

## EXPERIMENTAL SURGERY OF THE LUNGS.

### I. THIRTY ANIMAL OPERATIONS UNDER POSITIVE PRESSURE.

(A PRELIMINARY REPORT.)

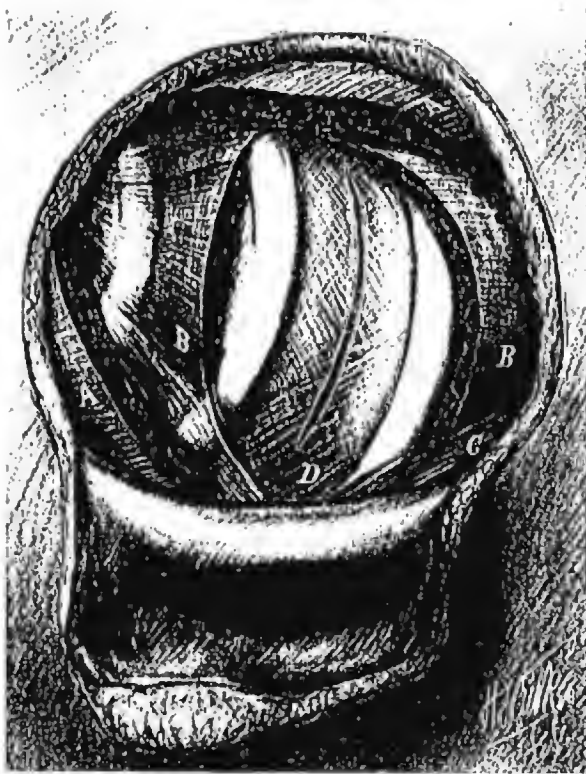
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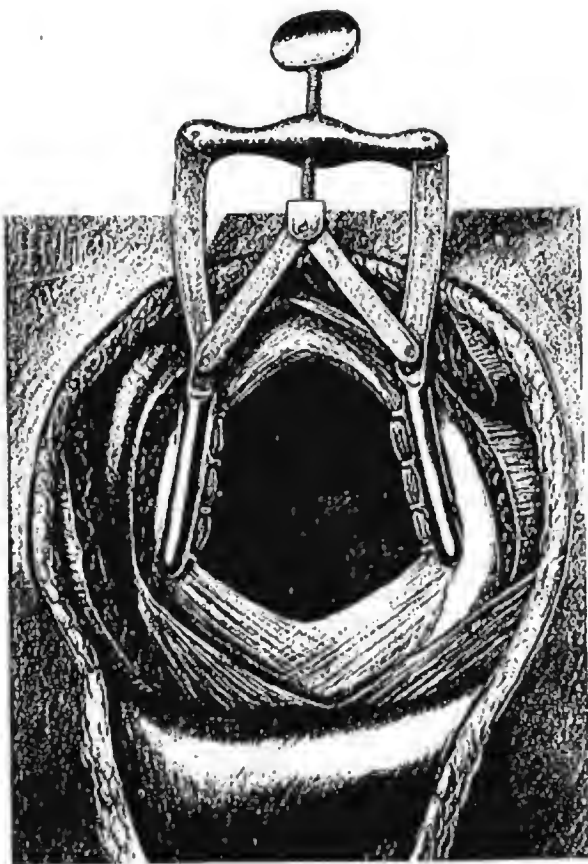
THE slow advances in surgery of the thorax during the eighteenth and nineteenth centuries are abundantly portrayed in the publications of the last ten years. I will omit them in this preliminary report. Suffice it to say that the year 1904 marks the beginning of a new epoch in the history of intra-thoracic surgery. I refer to the works of Sauerbruch and Mieuliez at Breslau, and of Brauer at Heidelberg. Most publications since that date have been based on the theories advanced by these men.

The comparative infrequency of intra-thoracic operations at the large surgical clinics in this country and in Europe, indicates at once the danger which is associated with operations performed under the older methods; and we are inclined to credit the few recoveries which have occurred rather to the "Hand of Providence" than to the skill of the operator.

Successful operations in the pleural cavity demand at least one factor,—the avoidance of lung-collapse. If atmospheric air is allowed to enter and remain in the normal pleural cavity the lung will collapse. The effect of lung collapse is a series of circulatory, nervous, and respiratory disturbances which, if collapse is continued, result in death. A discussion of the many theories as to the pathology of pneumothorax will be included in a second paper. The fatal effects of collapse of the lung must be avoided in one of two ways. Air must not be allowed to enter between the visceral and parietal



DRAWING 1.--Gridiron thoracic incision with skin flap. (AA) Pectoral muscle. (BB) Thoracic portion of rectus abdominis. (CC) Upper fibres of external oblique. (DD) Fascia covering intercostals, incised between 5th and 6th ribs.



DRAWING 11.—Showing use of rib-spreader. Jaws including intercostal stumps and pleural edges.

layers of the pleural cavity, thus forming an actual "pleural space" or else the lung must be kept artificially inflated. The former is the key note of all the older methods of avoiding collapse in operations in the chest. A safe operative field if not already caused in the form of inflammatory adhesions between the two pleural layers, has been produced by the artificial formation of such adhesions through injections of irritating media, by prophylactic suturing of the pleura layers around the field to be operated, or lastly by the immediate withdrawal into the pleural opening of a lobe of the lung, thus preventing the further entrance of air, at the same time preventing the actual retraction of the lung towards its root, which in itself is sufficient to cause circulatory changes which result in threatening symptoms. The disadvantages of these earlier methods of avoiding collapse are self-evident. Inflammatory processes cannot always be trusted to connect the parietal pleura with deep-seated abscesses, thus giving clinical evidence of their localization, and a walled-off channel for their approach. It is also apparent that in the absence of such localized signs, an artificially produced adhesion, as by the use of chloride of zinc or suture, may not be made at a point through which the cavity to be emptied can be reached. Such mistakes lead to unnecessary probing of normal lung tissue in the vain search for pus.

If an operator ventures the risk of pneumothorax by opening the cavity and withdrawing a neighboring lobe through the wound to prevent collapse, he immediately obstructs his approach to exploratory procedures and at the same time causes respiratory and cardiac disturbances by the irritation of the vagus terminals from manipulation and traction of the lung. (See sections of tracing at this stage of operation.) Releasing the traction will again be attended with signs of lung collapse. A certain amount of intra-thoracic work can be done before threatening symptoms require the replugging of the wound. Such operating is, however, too precarious to permit of due care,—the danger point is constantly too imminent.

The one salvation then of these methods of operating is the presence of adhesions and it seems reasonable to assume that the majority of successful intra-pleural operations have been done in the presence of such adhesions; in fact most lesions of this region are accompanied by more or less inter-pleural involvement.

Until free exploratory pleurotomy and intra-thoracic inspection become thoroughly safe procedures the advance of intra-pleural surgery must be restricted.

The recent somewhat promising wave of advance is along the lines of artificial inflation of the lungs by means either of negative pressure, applied to the outer surface of the lungs, or positive pressure to its inner acrating surfaces. Since the seventeenth century, varieties of artificial respiratory apparatus have been used in physiological laboratories to prevent lung collapse during experiments on the respiratory and circulatory apparatus.

In his publication of 1904 Sauerbruch<sup>1</sup> states his objections to the use of such positive pressure respiratory apparatus for experimental surgery in which the recovery of the animal was desired. His objections are as follows:

1. The change in the method of breathing. (That is to say rhythmically inflating the lungs regardless of the normal reflex mechanism of breathing.)
2. Interstitial emphysema of the lung, as result of the artificial inpumping of air into the lung.
3. The effect on the circulation.
4. The persistence of a pneumothorax at the abandonment of the artificial inflation.
5. The great loss of heat.
6. The great danger of infection to the pleura as a result of the extensive exchange of air in the pleural cavity.
7. The necessity of tracheotomy.
8. The difficulty of narcosis.

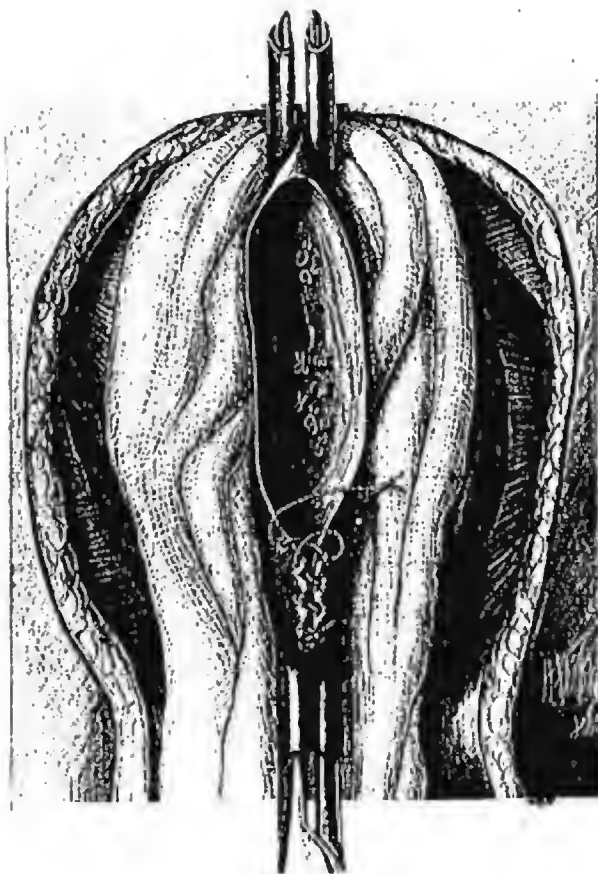
Sauerbruch, therefore, constructed the pneumatic chamber which is now well known. To describe briefly, the

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<sup>1</sup> Mittheil. a. d. Grenzgebieten z. Medizin u. Chirurgie, xiii, b. d., p. 399.



DRAWING III.—Lower right lobe withdrawn and clamped.



DRAWING 1V.—Showing boat shape of stump and beginning of first row of inverting sutures.

operator and assistant, and the patient's body and extremities are within the cabinet, the head protruding through a rubber drum at one end into the outside air. The etherizer is, therefore, outside the chamber, and the anesthetic can be administered in the usual way. A negative pressure can be maintained within the cabinet which does not embarrass the breathing of the occupants, but is sufficient to prevent collapse of the lungs in intra-thoracic operations. Sauerbruch claims that by this negative pressure inflation, all of the above eight objections to the use of the ordinary artificial respiratory devices are obviated.

A few months after this publication, Brauer, who with Petersen had been experimenting with the positive pressure in Heidelberg, published an article in support of the method. He did not attempt to deny the success of the cabinet in avoiding the symptoms of collapse, nor did he enumerate objections either to its construction or possible harmful effects. He devoted himself largely to the description of his own apparatus, and refutes at great length the third of Sauerbruch's objections; namely, the disturbances of circulation resulting from the use of the positive pressure, which are supposed to be greater than under negative pressure.

The apparatus recommended by Brauer consists, in brief, of a metallic box, in one side of which a large rubber collar is inserted. The patient's head is inserted through this collar, which in turn is adjusted air-tightly around the neck. The patient's face can be watched through a glass window in the top of the helmet. Holes in the side walls, fitted with elastic cuffs, admit the etherizer's hands without leakage around them. Ether is introduced into a compressed air or oxygen conduit, which leads to the helmet. Exhaled air is provided with an exit which meets the resistance of a water column.

As stated by Brauer, the negative pressure cabinet possesses the great disadvantages of costliness and weight. The expense of construction is sufficient to render it unobtainable to other than well provided hospitals, and quite out of the



question for private work. Its size and weight render transportation impossible. It is, however, being given a practical trial as to its serviceability, with considerable success.

The objects in the following investigations were as follows: 1. To perfect a suitable apparatus for the employment of the positive pressure method. 2. To test the objections of Sauerbruch, first on the basis of practical surgical experiments and, provided these experiments were satisfactory, to further examine his statements with blood-pressure, respiratory and cardiac tracings to see whether these functions are much disturbed when a perfected positive pressure is applied.

The apparatus which I have constructed, as shown in photograph A, has proved most satisfactory. It can be recommended as practical at least for experimental surgery of the thorax, for experiments in physiology, and pathological physiology, and for anatomical demonstrations of the relations and appearances of the thoracic viscera. It obviates the necessity of an etherizer, and can readily be controlled by the person operating. For other than thoracic operations, it can be so adjusted that the anesthesia is administered automatically for an hour, without danger of over-etherizing.

Previous to the operations on dogs described below, seven experiments were performed on cats to familiarize myself with the following factors:

1. Effect of ether when applied under air compression.
2. Amount of heat required for ether vaporization.
3. Possibilities of masks of various shapes for application to animal's face for administration of ether under positive pressure.
4. Construction of apparatus to hold such mask firmly in position.
5. Effects of variations in size of afferent and efferent tubes to mask.
6. Different methods of regulating amount of anesthesia administered.
7. Results of pneumothorax with small opening.

8. Results of "wide-open" pneumothorax.
9. Results from manipulation of lungs.
10. Effect of positive pressure application under the above three conditions.
11. Effect of variations in this pressure.
12. Effect of excision of greater or less portions of either or both lungs, under positive pressure.

Having thus become familiar with the well-known fact that the thorax may be opened and large portions of the lungs removed under the influence of air pressure without causing immediate death, I commenced the following series of operations to determine how extensive operations may be performed on the lungs with a reasonable hope of recovery.

CASE I.—Operation: *Simple pleurotomy. Rib excision.* Result: *Death. Cause: Septic pleuritic effusion,* March 22, 1907. Small mongrel, weight 15 pounds. Asepsis: not thorough. Face mask poorly fitting. Simple, temporary, positive pressure device: inconvenient, favoring sepsis.

Skin and muscle flap triangular in shape to expose fifth rib near sternal end. Fourth and fifth intercostal muscles divided near 4th and 5th ribs respectively. One inch of 5th rib with attached intercostals excised and lifted from parietal pleura. Latter incised 4 cm. Action of right lung observed for half hour. Continuous cat-gut suture with turns 8 m.m. apart picking up pleural edges, and when possible intercostal stumps. Pectoral muscle stumps approximated with interrupted sutures. Interrupted silk to skin. Time about 1 hr. 30 min. Collodion painted over wound: no swathe. Animal walking with stagger 15 minutes after removal of ether.

March 23, 1907: Temperature 103. Tail wagging. Able to stand on hind legs leaning.

March 26, 1907: Temperature 102 (normal). Respiration increased and somewhat labored: mucous membranes cyanotic. Dullness on percussion of right chest. Lying down. Died during afternoon.

*Autopsy,* March 26, 1907: Skin incision clean: muscle suture parted one-fourth its length. Pleura lying open below hole in muscle. Twelve ounces of sero-hemorrhagic fluid in right chest. Lung partially collapsed. Area of thickened visceral pleura over middle lobe. No fibrin or lymph. Left chest normal. Ounce of fluid in pericardial sac. Excised lung readily inflatable throughout.

Diagnosis: Leakage in wound. Pneumothorax. Pleuritic effusion: sepsis.

CASE II.—Experiment: *Prolonged application of positive pressure without pleurotomy.* Result: *No ill effects.* March 29, 1907: Black and white fox-terrier, female; weight 14 pounds. Object: To determine whether pleuritic effusion in Case I. was caused by use of positive pressure with possible congestion of lung and mechanical transudate.

Animal etherized. Positive pressure apparatus applied and animal kept under it for about two hours with 6-8 mm. of mercury resistance. Pneumograph applied to abdomen and tracings made.

Animal came quickly out of ether within half an hour of removal of cone, and was able to run upstairs to the roof.

Three days later animal appeared entirely normal and showed no cyanosis or difficulty of respiration. It was decided that there had been no ill effects from positive pressure apparatus as such.

CASE III.—Operation: *Simple pleurotomy*. Result: *Recovery after localized empyema*. April 2, 1907: Same dog as Case II. Object: To improve on technique of closing pleural cavity hermetically. Asepsis not thorough.

Curved incision in anterior right thorax, making semi-circular skin and muscle flap, diameter  $2\frac{1}{2}$  inches. Internal and external intercostal muscles of 5th interspace dissected with difficulty away from parietal pleura, leaving interosseous field  $\frac{1}{2}$  inch in diameter. Interosseous vessels controlled with pressure. Pleurotomy. Respiration became deeper and less frequent: mucous membrane of mouth seen through glass mask to be cyanotic. Resistance in water column increased to 8 cm. of water. Mediastinum blown forcibly into wound. Finger introduced to posterior thoracic wall and withdrawn. Attempt made to suture pleural edges but latter had retracted under ribs so that perfect approximation was impossible. Air could be heard rushing between turns of continuous stitch at respiration. Trusted that interrupted cat-gut suture to muscle and silk to skin might render flap means of air tight closure.

Immediately after recovery from ether respirations were somewhat labored.

April 3: Temperature 106; respirations 40; pulse 160. Inclined to lie down.

April 4: Temperature 105; respirations 45; pulse 170. Swath and dressing soaked with serous discharge. Removed. Air heard sucked in and out of chest through wound. Dressing applied with pressure.

April 5, 6, 7: Eating well. More active. Stitches out on fourth day. Wound septic but granulating. Free access of air in and out of cavity was noted.

Dog became normal in habits at end of one week. Profuse purulent discharge from wound continued for five weeks, and gradually granulated to closure.

Diagnosis: Air leakage in wound: sepsis: localized empyema.

*Autopsy*: Killed with ether, eight weeks after operation. Cohesions between original wound and adjacent surfaces of muscle and lower lobes. No fluid or pus in cavity. Lung tissue apparently normal.

CASE IV.—Operation: *Simple pleurotomy*. Result: *Recovery*. Object: To improve technique of closing cavity and to increase asepsis. Recovery of Case III was doubtless accidental, owing to early pleural adhesions localizing pneumothorax and suppuration. April 7, 1907: Brindle mongrel, female; weight 18 pounds. Careful aseptic precautions. Chest shaved. Soap and water. Alcohol. Sterile towels.

Positive pressure 4-6 mm. of mercury. Pressure introduced before pleurotomy, thus avoiding dyspnoea. Pneumograph tracings showed no change, but slight increase in depth of respiratory excursions. Gridiron incision. Semicircular flap with convexity downwards. Muscle divided separately in same curve. External oblique origin divided at right angles with skin incision exposing 5th, 6th and 7th ribs. Sixth rib incised,  $\frac{3}{4}$  inch, together with half of intercostal muscles above and below respectively. Less intercostal bleeding than in Case III. Pleurotomy  $\frac{3}{4}$  inch. Pleural cavity and lung not handled. Pleural stitch (black intestinal silk with smallest curved eye needles) included portion of intercostal stumps which were, of necessity, stitched to cross space occupied by excised rib. Second row continuous suture, picking up same tissues. External oblique approximate with cat-gut. Also pectoral muscle. Subcutaneous layer with catgut. Interrupted and continuous silk to skin. Time 2 hours, 30 minutes. Prompt recovery from ether. Walking in 20 minutes; breathing not labored.

April 8: Pulse 108; respirations 30. Running about. Jumps to 2-foot bench. Convalescence entirely normal. Milk diet for two days, then raw meat. Dog presented no symptoms or signs from time of operation. Wound solid on fourth day. Stitches out on seventh day. Two weeks later used again in physiological experiment.

CASE V.—Operation: *Excision of tip of right middle lobe*. Result: *Death on sixth day*. Cause: Sepsis. Pneumothorax from leakage of stump. Object: Encouraged by success of Case IV, attempted to make larger pleural cavity opening with excision of piece of lung-tissue.

April 16, 1907: White mongrel, female, weight 20 pounds. Chest shaved on previous day; reshaved, scrubbed with soap, water, alcohol and corrosive. Square skin flap (3 inches diameter) reflected outwards, exposing right 4th, 5th and 6th ribs. Pectoral and external oblique muscles not at opposing angles. One inch of 5th and 6th ribs excised with intercostal muscles connecting. Just before pleurotomy animal suddenly stopped breathing. Probably due to excess of ether. Apparatus converted into artificial respiratory one, and breathing restored by twelve rhythmical inflations at intervals of about 12 seconds. Breaks in asepsis repaired, and operation continued. Parietal pleura divided diagonally across field. Tip of middle lobe ligated with catgut, and amputated  $\frac{1}{8}$  inch from ligature. Stump dropped back. Mediastinum, blown into wound by pressure from unoperated side, interfered with suture of pleura. Scalpel stuck into left chest and turned to allow left pneumothorax. Mediastinum retracted to its median position. Pleural edges approximated with continuous silk at end of wound. Two interrupted sutures in centre, the latter of which was drawn tight at end of inspiratory excursion (see correction in later operations). Pleural stitch leaking. Lateral tears due to lack of support of intercostal muscle tissue. Wound sutured in layers. Scalpel wound of left chest closed with one skin stitch. Tight swathe applied over sterile dressing.

April 17: Temperature 101.6; pulse 150; respirations 60. Dog languid, but drinking.

April 19: Temperature 105; pulse 180; respirations 75. Slight dullness elicited by percussion of right chest. Decided not to attempt secondary measures.

April 22: Died. In three days previous food and water refused.

*Autopsy.*—Skin and first muscle layer clean and dry. Pleural wound gaping with continuous silk stitch lying free in cavity wrapped in fibrin. Right chest contains 10 ounces of sero hemorrhagic fluid with purulent sediment. Visceral and parietal pleurae covered with fibrinous exudate and lymph, which could be removed with finger. Lungs excised and inflated. Ligature had slipped off tip of movable lobe and air was heard escaping from pin-point opening in stump. No pneumonie or atelectatic areas in either lung. Left pleural cavity contained 5 ounces of similar fluid without fibrin shreds. Left lung normal. Cultures of pleuritic fluid saved for examination.

The operation as such of Cases I, II, IV and V, with a mortality of 50 per cent., are simple to the extreme. They are reported, however, to show the necessity of absolute asepsis and painstaking technique for the hermetical closure of the lung stump and of the chest wall. Just why a pleuritic effusion occurs in these fatal cases will be discussed in a later paper on the basis of pathological physiology. I was, however, convinced at this time by the cat experiments, and by the success of Cases II, III and IV, that the cause of fatalities must be sought, not in the positive pressure resistance to the lung, but rather in the intrinsic unreliability of the apparatus used in the above cases, in the breaks in asepsis necessitated by this unreliability, and lastly in undeveloped surgical technique. It was evident that the removal of two ribs together with intercostal musculature rendered approximation of pleural edges difficult, and that of intercostal stumps impossible. It seemed advisable also to adhere to simple pleurotomy until technique was perfected.

The apparatus used in the above cases was an improved one, consisting of a small ether bottle with rubber-tube connections for conduction of air; also an outlet tube to a water bottle. The mask was smaller than that shown in photograph A.

CASE VI.—Operation: *Simple pleurotomy. One rib excised.* Result: *Recovery.* Object: To obtain recovery after simple pleurotomy under positive pressure of improved apparatus. Two-rib excision abandoned.

July 19, 1907: Lemon and white pointer (mongrel); weight 30 pounds. Dog had been etherized under positive pressure on two days previous. Considerable muus in pharynx doubtless resulting from the above. All aseptic precautions of a hospital surgical operation. Crescencic incision on right chest with convexity  $\frac{1}{2}$  inch from median line and ends approaching axilla. Pectoral muscle fibres cut transversely, also pectoral aponeurosis of external oblique. Fascia covering ribs incised over and parallel to 5th rib. Saw cut through cartilage of 5th rib  $\frac{1}{2}$  inch from sternum. Another saw cut  $1\frac{1}{2}$  inches towards axilla. Ribs then carefully dissected from parietal pleura and from its intercostal attachments. Intercostal oozing readily stopped with pressure. Positive pressure resistance increased to 7 cm. (water) by lowering glass tube in water column. Pleurotomy (1 inch). Pressure so regulated that lungs hugged parietal wall, but did not protrude through opening. Mediastinum bulging into wound, however. Respirations quiet and regular. Attempt made to reduce resistance to 4-5 cm. Respirations became labored; 7 cm. restored. After one-half hour of observations pleural stitch commenced. No. 1 silk, fine curved round needle. Suture picked up pleural edges together with intercostal stumps, which, by above method of rib excision, lay in close apposition to pleural edges. Turns  $\frac{1}{8}$  inch apart. At one point, however, where pleura was devoid of intercostal support, a cross tear occurred after continuous stitch was tied. Repaired by a cross stitch. Still some air leakage. Second continuous row of sutures, including fascia covering intercostal and picking up pleural stitch, prevented further leakage. Catgut to muscle layers. Pagenstecher's linen to skin.

Dog allowed out of ether too soon before swathe was applied. Considerable unnecessary strain on stitches resulted. Under ether 2 hours.

July 22: Temperature 102.2 (normal); pulse 82, irregular; respirations 26. Languid.

July 24: Temperature 104.4; pulse 54, irregular; respirations 20 (normal). Active; apparently in normal condition.

July 25: Stitches removed: slight redness in  $\frac{1}{2}$  inch of incision. Cotton collodion cocoon.

July 27: Cocoon removed: wound clean and dry. Dog well. Temperature 101. Pulse 94; respirations 20.

Sept. 16: Since last note dog's convalescence has been normal except for diarrhea and loss of weight following ingestion of stale meat. He recovered from this before autopsy. The pulse has been irregular since operation.

*Autopsy*, Sept. 16, 1907: Dog killed with ether. Line of incision clean and indistinct. Slight fullness at lower end about size of a pea. One dram of pus escaped from this point and was traced to a small cavity in muscle layer containing a free chromic gut stitch. Muscle union firm and adherent to pleural suture below. Pleural scar divided. Adhesions from between pleurotomy wound and pericardium (probably explaining irregularity of pulse). Light easily broken adhesions between pleurotomy scar and adjacent surfaces of middle and lower right lobes. Lungs

excised and inflated. Found to be normal throughout. No hemorrhagic, emphysematous or consolidated areas seen macroscopically.

**CASE VII.**—Operation: *Simple pleurotomy. One rib excised.* Result: *Recovery.* Object: To repeat operation of Case VI, to improve rib resection and suturing. At this time resection of rib seemed to me imperative to obtain room enough to operate on lungs.

July 20, 1907: Fox-terrier, male; weight 20 pounds. Technique identical with previous operation except that intercostal muscles were carefully preserved and no lateral tears occurred in pleural stitch. Dog came out of ether slowly, and when left in recovery room was unable to stand. Prognosis looked unfavorable.

July 21: Dog lively and active as before operation. Milk diet taken eagerly.

July 22: No symptoms; solid food.

Summary of daily chart:

July 22:	Temp.	102;	pulse	100;	resp.	panting with heat.
" 24:	"	102.0;	"	120;	"	" " "
" 27:	"	102;	"	90;	"	25
" 29:	"	102;	"	105;	"	23

Skin stitches infected and removed on the 5th day. Secondary healing in two weeks.

Sept. 24: Convalescence has been normal throughout. Dog killed with ether.

*Autopsy:* Right chest opened in 7th intercostal space. Finger introduced and pleural surface of original pleurotomy explored. Smooth serous covering at this point with no adhesions to pericardium or lungs. No fluid in cavity. No adhesions between lobes of lungs. Layers of thoracic wound firmly cicatrized and free from signs of infection.

**CASE VIII.**—Operation: *Simple pleurotomy, 2-rib excision.* Result: *Recovery; after localized empyema.* Object: To attempt a larger pleural opening before attempting lung resections. Sub-periosteal resection attempted, but found difficult with such small structures. Attempted two-rib method again.

July 21, 1907: French bull bitch (white); weight 20 pounds. Grid-iron incision down to level of ribs. Fifth and sixth ribs each sawed near costochondral articulation, and again one inch and a half nearer axillary line. Both sections together with 5th intercostal muscle group removed, leaving stumps of 4th and 6th intercostal muscles as long as possible. A right angle tonsil-knife was successfully used to separate ribs from pleura. Sub-periosteal resection of rib not practical in small animals. Pleurotomy of one inch. Respirations under pressure observed, but pleural cavity not disturbed. Mediastinum inclined to puff into wound, especially during forced expirations when ether was "light." Pleural edges alone approximated with provisional mattress stitches later drawn up through pectoral muscle and tied. Intercostal stumps could not be stretched across space left by two-rib excision, so pectoral muscle was sutured over pleura. Approximation of this layer poor at sternal end. Pectoral muscle sutured with interrupted and continuous, Pagen-

steelier linen. At completion of suture slight leakage could be heard near axillary stump of 6th rib which had torn open the pleura at this point.

July 22nd: Temperature 101.6; pulse 152; respirations 56. Dog somewhat languid.

July 23rd: Temperature 104; pulse 176; respirations 84. Condition much worse. Respiration labored. Presents all symptoms of pleuritic effusion, with probable infection. Presuming that leakage was occurring in wall, an attempt was made to expand lung under pressure, together with aspiration to empty cavity and favor pleural adhesions. Seven to eight cm. (of water) pressure applied with apparatus. Trochar inserted dog's axillary line at 6th interspace. Rubber and glass tube extension to trochar. Mouth suction. One-half ounce of bloody fluid aspirated by this method. Tube suddenly withdrawn and throacentesis wound clamped and tied. Lung had thus been expanded by both positive and negative pressure. Animal apparently much revived by above procedure. Ran up three flights to recovery room. Five hours later respirations 64.

July 24th: Marked improvement. Temperature 102; pulse 120; respirations 52.

July 25th: Marked fluctuating swelling under skin flap. Skin stitches granulated at one point. Three ounces of sero-hemorrhagic fluid escaped, more than enough to have come from flap alone. Large absorbent dressing applied.

July 26th: Dressing soaked. See chart.

July 28th: Dog in fine condition. Condition has evidently become one of a localized empyema. Drainage continued. Discharge now purulent.

Sept. 15th: Sero-purulent fluid discharged from wound for five weeks, with gradual closure. Dog meanwhile active and eating well.

*Autopsy*, October 25, 1907.—Dog entirely normal since last note. Few adhesions connecting length of pleural incision with adjacent surfaces of lower and middle lobes. Middle and lower lobes slightly adherent at their adjacent surfaces. No fluid in cavity. Lungs excised and inflated. Both lungs normal and functional in every respect. Considering seriousness of dog's condition two days after operation, the pleural cavity showed little signs of previous disturbance.

CASE IX.—Operation: *Excision of 1½ inch tip of right middle lobe*. Result: *Recovery*. Object: Satisfied from above recoveries that simple pleurotomy with excision of piece of one rib was a reliable procedure, it was decided to adhere to this technique of closure, and to attempt excisions of lung tissue. There seemed to be reason to believe that fatalities resulting could now be ascribed to the lung excision, and not to faulty closures of cavity.

July 22, 1907: Tiny mongrel brindle, female; weight 12 pounds. Absolute aseptic precautions. One and one-half inch of 5th rib excised. Pleurotomy. Mediastinum in this case showed no tendency to blow into wound. Tip of middle lobe lying in immediate vicinity seized with smooth forceps and drawn out of wound. Tongue of lobe clamped with curved half-length blades protected by rubber tubing. Triangular piece then



amputated  $\frac{1}{8}$  inch from clamp. Continuous over-and-over stitch to stump. No vessels separately tied. Clamp removed. Two ends of stitch tied together, making stump conical in shape. Circular linen ligature at point of removed clamp. This tie yielded suddenly at end of first knot, as though cutting through. Pleural stitch satisfactory and strong. Excessive (10-12 cm.) pressure applied as knot was tied in pleural suture: with hope of driving air out of cavity just previous to closure, thus approximating lungs to thorax wall and preventing pneumothorax. Silk to muscle layers. Pagenstecher linen to skin. Binder with firm pressure.

July 23rd: Dog inactive, but apparently not sick.

July 24th: Temperature 104; respirations 26; pulse 140; question whether this temperature indicates pleurisy. Low respirations point against this possibility. Dog lies in corner, and growls when approached.

July 25th: Temperature 103; pulse 130; respirations 20. Eating well.

July 26th: Slight leakage of serous fluid at one end of wound, apparently from between layers of wall.

July 28th: Wound dry and solid. Dog lively and well.

Sept. 26th: Remained in absolutely normal condition to time of autopsy. Has gained about five pounds in weight.

*Autopsy*, Sept. 28, 1907.—Superficial pus formed between pectoral and intercostal layers. Intercostal layer strongly intact. Incision made in 7th space. Adhesions found between lower lobe and diaphragm; between pericardium and pleural wound, including stump of amputated lobe. Adhesions also between upper lobe and posterior thoracic wall, between middle lobe and pericardium. There was also a light adhesion between pericardium and left middle lobe. Lungs excised and inflated, and found normal throughout. A small portion of right middle lobe lacking. Stump one inch in diameter. Numerous adhesions covering stump. Specimens in toto frozen for future reference.

*CASE X.*—Operation: *Excision one-third of upper lobe*. Result: *Recovery*. Object: Dog IX having no threatening symptoms, a more extensive lung excision was attempted.

July 25, 1907: Lemon and white fox-terrier; weight 16 pounds. Technique of pleurotomy same as in Case IX, with excision of one rib. Pleural opening, one inch. Five minutes after pleurotomy, dog's respirations became shallow and less frequent. Probably due to excess of ether. Opening closed by traction on presenting lobe, and respirations were restored to normal. Presenting lobe clamped. Amputated stump sutured with continuous over and over silk. When clamp was released profuse hemorrhage occurred. Stump transfixed twice and ligated with Von Brunn linen. Stump dropped back, and pleura stitched. Pectoral muscles well overlapped, making good support of pleural stitch.

July 26th: Languid. Milk diet.

July 27th: More active. Doing better than expected.

July 28th: Somewhat sluggish. Respirations 30 and somewhat labored, but no signs of dyspnoea. Possible that respiratory stretching of pectoral muscle caused pain which gave appearance of difficulty in breathing. Lameness of right fore-leg more marked than previous cases.

July 29th: Wound clean, stitches removed. One drop of serum in one stitch hole. Dog coughs in low voice occasionally.

Aug. 4th: No coughing. Hungry for solid food.

Aug. 11th: Discharged well to roof.

*Autopsy*, Sept. 28, 1907 (2 months).—Killed with ether

Muscle and skin in region of incision were removed in one layer, and the pleural stitch was found solid. It is evident that there is considerable atrophy of the intercostal muscles in these cases.

An incision was then made two intercostal spaces below that where operative incision was made, and the finger introduced upwards to the pleural side of thoracotomy wound and a light adhesion was found between the middle lobe and the pleural scar. The left chest was then opened and the lungs and heart removed in toto, including sections of those ribs on the right to which right middle lobe was adherent.

The triangular piece described in account of operation proves to have been taken from a tongue of the upper lobe and the adhesions of the middle lobe was a coincident due to proximity of the same to the pleural opening. In fact, the localization of this adhesion point on the parietal-anterior surface of the lobe suggests to me that the lung must have been in a normal state of inflation immediately after the operation at a time when such contact adhesions would doubtless be formed.

The stump of the upper lobe was connected by a goose-neck adhesion reaching across to the pericardium. It was really of little apparent significance.

Both lungs inflated normally and it was interesting to compare the two upper lobes when under inflation. The stump of the resected portion of the right upper lobe was not more than a half inch in length, although the operation describes a sutured stump of two inches and a half. On comparison with the opposite lobe, however, it is evident that the apical tongue of this lobe is lacking, thus changing the shape of the parietal surface from pear shape to a more quadrilateral shape with rounding corners.

CASE XI.—Operation: *Excision one-half of upper lobe*. Result: *Recovery*. Object: Satisfied that apparatus is practical when properly handled; also satisfied that technique of wall closure is proving reliable, and that asepsis is improved, determined to limit myself to simple pleurotomy with excision of more lung tissue.

July 28, 1907: Brown and white mongrel hound; weight 22 pounds. Technique of thoracotomy unaltered. One and one-half to two inches of 6th rib excised. A larger portion of presenting lobe included by clamp. After amputation two rows of continuous linen were employed to stump. Lobe transfixed once proximally to clamp at median point, and as clamp was released stump was ligated in both directions. To be noted here that a simple "curved half-length" without rubber protection by blades has been used for clamps in the above operations. Time under positive pressure 2 hours.

July 29th: Milk diet taken well.

July 30th: Takes solid food greedily.

Aug. 1st: Temperature 102.4; pulse 105; respirations 15. Somewhat inactive and lame, but not sick.

Aug. 3rd: Dressing and stitches entirely removed. Drop of pus in one stitch hole at axillary end of incision. Dog running about to-day.

Aug. 8th: Wound entirely dry and clean. Temperature 102; respirations 20; pulse 75. Aug. 11th: Discharged well to roof to complete convalescence interval of 8 weeks.

Suturing stump and thoracotomy wound consumes an apparently excessive amount of time, but the forced movements of the chest and the fluttering mediastinum, and the occasional interference of the pericardium, render careful approximation with fine needles a slow process. Lack of an assistant added to time expended.

CASE XII.—Operation: *Excision of right middle lobe.* Result: *Recovery. Death in four weeks from unknown causes.*

July 31, 1907: Brindle Boston terrier mongrel; weight 25 pounds. Object: To increase extent of pneumnectomy gradually. To attempt total removal of right middle lobe.

Gridiron incision. Pectoral muscle divided transversely to fibres. Pectoral belly of rectus and fascia over ribs cut parallel to and over 5th rib. Usual rib excision, saving all intercostal muscle tissue. Intercostal arteries required tying in this case. Pleurotomy one inch. Dog not being susceptible to ether remained "light" throughout the operation. As usual in such cases, expirations were violent as though effort was being made to blow away resistance of water column. Tendency under such conditions to lung collapse is, of course, much reduced, so that the whole operation was conducted under an actual resistance of only 3 cm. of water, which, however, by voluntary forced expiration was increased to 7-8 cm. Mediastinum was consequently blown violently into wound in form of finger-cot shaped scar, as result of unequal pressure in two pleural cavities resulting at expiration in the extension of the left lung and mediastinum over to the pneumothorax side. The bulging mediastinum was walled away with gauze wick.

Tip of lower lobe seized, but found unyielding, and dropped back with laceration of tissue by use of forceps. Middle lobe then drawn well out of cavity and clamped as near root as possible with clamp remaining extra-thoracic. Stump sutured over-and-over with silk. Transfixed proximal to clamp with Pagenstecher linen, and tied in both directions as clamp was released. Mediastinal wick removed. Respirations now less forced, mediastinum quiet.

Satisfactory pleural stitch, including intercostal stumps, and fascia covering them. Slight leakage at end of wound showing necessity of carrying stitch to extreme limits of intercostal incision. Second row of sutures to same tissues. Von Brun linen continuous to muscle, continuous linen stitch to skin. Considerable bleeding in wall. Time 2 hours.

August 1st: Apathetic.

August 2nd: Languid, but not sick.

August 3rd: Temperature 102; pulse 142; respirations 40. More active. Dressing removed.

August 6th: Temperature 102; pulse 150; respirations 28. Wound entirely clean and flat.

August 8th: Temperature 102; pulse 150; respirations 24.

August 12th: Discharged well to roof.

August 26th: Dog has been normal and eating well, but never active.

Question whether dog is naturally logey.

August 27th (4 weeks after operation): Dog found dead on roof, with maggots in mucous membrane. Dog fight had been overheard on previous day, but there were no superficial signs of violence.

August 28th, *Autopsy*.—Small accumulation of pus in muscle layer, with loose linen stitch in its midst. Pleural scar solid and clean.

Further report by S. B. Wolbach as follows:

The right lung is collapsed; at the apex is compact; markedly post-mortem. As viewed from behind, the middle and lower lobes are adherent to the chest wall to the 3d, 4th, 5th, 6th, and 7th ribs. From in front the pericardium and anterior border of the right lung are adherent to the chest wall, formed by the 4th, 5th and 6th ribs. A portion of the 5th rib is missing and for a distance of 4.5 cm. the chest wall is made up of fibrous tissue. On incision a pus cavity is exposed in which lie several sutures. The lower lobe of the left lung is apparently normal.

The heart is united to the pericardium by loose tough fibrous tissue over both ventricles.

Right auricle and ventricle is adherent to the chest wall below the stump of the lung; markedly post-mortem; apparently normal. Tissues about stump of lung firm and clean.

CASE XIII.—Operation: *Excision of 3 right lobes*. Result: *Death*. Cause: *Infection of both pleural cavities*.

Aug. 2, 1907: Tan colored bull-bitch; weight 24 pounds. Object: Excisions of individual lobes and parts thereof have been so persistently successful in the last few operations that more radical procedures seemed possible. Instead of gradually increasing the amounts excised, total excision of lobes was attempted.

Same thoracotomy technique, with excision of piece of fifth rib. Animal employing forced expiration owing to unsusceptibility to ether causing hernia of mediastinum. At one stage it was necessary to suspend operation and plug wound with gauze, at same time lowering pressure resistance to 3 cm. on account of these forced expiratory movements.

Middle and upper lobes consecutively withdrawn from thorax, clamped, amputated, sutured, and transfixed at stump. No vessels or bronchi tied separately. Ends of continuous sutures to stumps tied together.

Lower lobe treated likewise, except that two vessels were ligated before stump was sutured. Finger exploration revealed no palpable lung tissue remaining. During pleural stitch pericardium constantly flapping

into wound. Pierced twice by needle. Respiration at same rate after pneumectomy until dressing was applied and pressure removed. At this moment breathing became more rapid. Time 2 hours, 30 minutes.

August 3rd: Temperature 102.6; pulse 135; respirations 88. Dog's general appearance no different than in animals with partial pneumectomy on first day after operation, except for high respirations. Temperature seems to contraindicate sepsis.

August 4th: Temperature 102; pulse 110; respirations 65. Sluggish condition, but inclined to walk and join other dogs.

August 6th: Temperature 101.6; pulse 165; respirations 60. Sick. Respirations high and labored. Right chest dull to percussion. Dog placed on board. Trochar inserted into 5th space, axillary line; 175cc. of hemorrhagic fluid escaped. Stringy sediment at bottom of graduate (culture). Puncture wound closed with suture. On standing fluid leaked through to dressing.

August 7th: Has refused nourishment for 2 days. Considerable improvement in general condition. Temperature 101.8; pulse 128; respirations 84. Drainage has ceased. Dog found dead at 2 P.M.

*Autopsy* (Wolbach).—"Skin incision perfectly healed. There is a small abscess containing about 3 cc. of pus. A piece of the 5th rib is missing. The excised portion of rib is about 4 cm. in length. There is a stump attached to the sternum about 1.5 cm. in length. The pleura of the lung is adherent to the pleura covering. The left lung above is adherent to the chest wall along the 4th rib. Below the lung is adherent to the 6th rib. On removal of the lungs a cavity containing pus is found between the lower lobe and the diaphragm. Holds in all about 50 cc. The adhesions of the lung to the chest wall are firm and fibrous in character. A portion of the middle lobe is missing. Vessels and bronchi leading to excised portions are normal. Both lungs in general are collapsed; deep red and atelectatic."

CASE XIV.—Operation: *Pleurotomy with 3-rib flap*. Result: *Death*. Cause: *Lung collapse from leakage*.

Aug. 4, 1907: Fox-terrier-beagle mongrel; weight 28 pounds. Object: Realizing that pleural opening in the above cases is too small for intra-thoracic operating in general, a departure from the above technique of pleurotomy was undertaken in the form of a rib flap. Apparatus worked satisfactorily, and no breaks in asepsis were detected.

Semi-circular skin-flap exposing 4th, 5th and 6th ribs for distance of 2 inches. Gridiron incision through pectoral and upper rectus origin. Cartilages of 4th and 5th ribs cut through. Bony portions sawed through 2 inches from cartilage cuts. Intercostal muscles of 3rd and 6th spaces cut at attachment to 4th and 5th ribs respectively. Tonsil knife used to separate rib flap from parietal pleura. Pin point punctures near axillary upper end of flap. Flap now bent back towards axilla, exposing pleura to extent of area  $1\frac{1}{2}$  inches square. Pleura incision across diagonally to direction of ribs. Each lobe of right lung withdrawn in turn and handled. Respiratory movements continued rhythmically. Pressure so regulated that lung was constantly lying flush with wound but not protruding.

Pleura, stitched with continuous silk from either end, plus two "interrupteds" in the middle. Lack of muscle support to pleural edges resulted in lateral tears at two points which could not be permanently repaired. Considerable air leakage in and out of cavity. Flap layed over and adjoining tissues at edge of flap stitched with linen. Ends of ribs and cartilages joined with mattress stitches, taking in cartilage or periosteum. Recut stumps could not be brought together across space. Pectoral was sutured carefully, however, and leakage could not be heard. Second continuous row in pectoral layer. Skin brought to close approximation with interrupted and continuous linen. Dog out of ether and walking to leash in 30 minutes.

Aug. 6, 1907: Refused nourishment. Expirations forced and characteristic of all above cases, with effusion and collapsed lung. Identical also with breathing of Case XIII, in which there had been practically a total pneumectomy. Temperature 102.6; pulse 150; respirations 60. Temperature seems to contraindicate septic pleurisy.

Aug. 7, 1907: Found dead in recovery room at 9.30 A.M.

*Autopsy* (immediately).—Skin stitch tight and dry. Immediately beneath was found direct communication with pleural cavity. Pectoral suture was intact, but axillary end of pleural stitch, where protected only by outer edge of rectus, was wide open. Directly beneath skin, therefore, an effusion was encountered which proved to fill the right thoracic cavity. This effusion was fibrinous in character. Both rib segments contained in flap had broken away from their sutures. Intercostal muscles of flap showed beginning of gangrene, doubtless from lack of blood supply due to injury to intercostal vessels. The parietal pleura was adherent to the collapsed right lung, and dragged with the latter to the posterior wall. Lobes were all atelectatic.

CASE XV.—Operation: *Excision ¾ of right middle lobe*. Result: *Recovery*. Object: Two departures have been made in the last two cases from a previously satisfactory procedure: 1st, excision of four times as much lung tissue, Case XIII; 2nd, attempt at rib flap in place of single rib excision. Since both operations having resulted fatally, it was decided to return to the original technique with more gradual increase of procedure.

August 9, 1907: French bull-terrier; weight 8 kilos. Original technique of pleurotomy with excision of two inches of 5th rib. Tip of presenting lobe seized. Lobe drawn out. Amputated. Stump-suture. Transfixation and ligation. Pleural stitch leaked at one point. No leakage through 2nd muscle layer. Pectoral suture not diagonal to pleural stitch.

Aug. 10th: Dog very apathetic, lying down, head low. Purulent discharge from both nostrils.

Aug. 11th: Refuses nourishment, pus discharge from eyes and nose. Respiration 18; temperature 102; pulse 100, irregular.

Aug. 12th: Water ounces 3 by rectum. Dog sick, but respirations are normal. Suspected that languor was due to rhinitis and conjunctivitis.

Aug. 16: Walking about. Less apathetic. Eating well.

Aug. 19th: Dressing disturbed for first time. Continuous stitch surrounded with lymph, removed. This condition of skin stitch likely to occur if latter is left in more than four days. Dressing omitted.

Aug. 20th: Scabs of sawdust over stitch wound of aid in healing.

Aug. 24th: Snuffles more active. Diarrhoea profuse. Eating well, however. Pulse still ranging between 125 and 150. Temperature and respirations normal. Diagnosis, distemper.

Sept. 6th: Discharges less. No rash has developed.

Sept. 15th: No symptoms of distemper. Dog entirely well. Gaining weight.

Oct. 13th: Dog has developed no symptoms of any sort.

*Autopsy* (9 weeks).—Thoracotomy wound clean and solid. Adhesions between right lower lobe and lower end of pleurotomy scar. Adhesion between stump of middle lobe and the pericardium. Also between stump and pleurotomy wound. Found that one-half of cardiac (middle) lobe has been removed. A small cyst the size of a pea bean was found in stump which contained a gelatinous fluid and which, when incised, allowed escape of air through pin point opening.

Right lung tissue presents microscopically no areas of atelectasis, pneumonia or emphysema. Left lung normal. Both lungs excised and inflated. Sketch made. Specimens frozen 12 hours after removal.

CASE XVI.—Operation: *Excision right middle lobe*. Result: *Recovery*. Object: To further establish the reliability of the above method of pleurotomy and partial pneumectomy.

Aug. 10, 1907: Irish terrier; weight 11 kilos. Well nourished, short hair. Rib excised without injury of pleura at any point. Pleurotomy of 1½ inches. Respirations continued to be regular and not dyspnoeic. Neighboring lobe withdrawn and amputated. Stump too long for "half length," resulting in slight wrinkling. Same suture to stump except that continuous was carried across and back. Stump transfixed and ligated.

Wall layers as follows: 1. Pleura and internal intercostal. No leakage after this suture. 2. External intercostal and fascia. 3. Pectoral and few cut fibres of external oblique. Apparatus satisfactory. Pulse 180 at end of operation. Temperature subnormal, 100.4. Respirations 60. Technique interrupted twice: 1. Cleaning mucus from cone. 2. Refilling ether bottle. Operation on whole more satisfactory than those above.

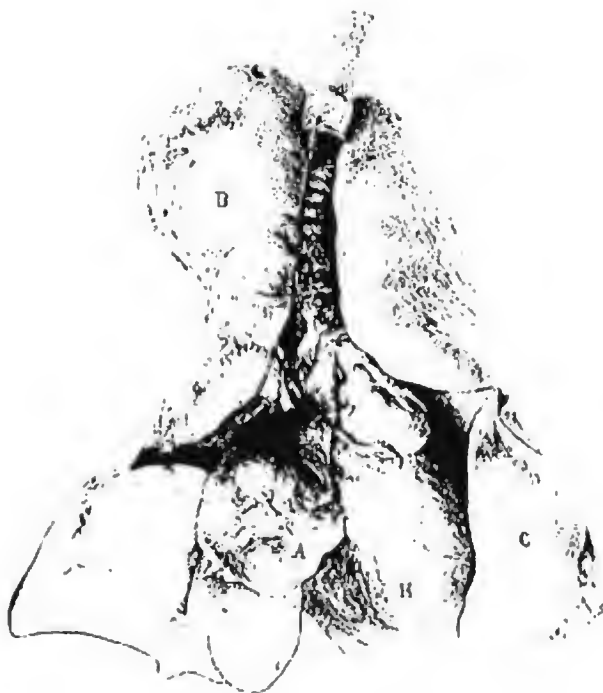
Aug. 11th: Solid food. Walking. Temperature 103.2; pulse 130; respirations 30. Prognosis good.

Aug. 12th: Pulse irregular. (See autopsy for pericardial adhesions.)

Aug. 15th: Stitches out; wound clean. (See chart of Case XVI.)

Oct. 10th: Eight weeks since operation. Dog has had an uninterrupted convalescence.

*Autopsy*.—Thoracotomy below original scar. Finger introduced and the under surface of pleurotomy wound palpated. It was covered with serous membrane and there were no adhesions except one to the pericardium, which was easily separated. The lungs were excised in toto and



CASE XVI.—Excision of right middle lobe. (A) Stump of excised lobe. (B) Right upper lobe. (C) Left middle lobe. (H) Heart.



inflated. After separating adhesions between stumps and adjoining surfaces of upper and lower lobes, it was found that all but a small portion of the right middle lobe had been excised. Specimen frozen. Thawed out, inflated and photographed five weeks later. The lungs and pleural cavity were otherwise entirely normal.

CASE XVII.—Operation: *Posterior thoracotomy*. Result: *Recovery*. Object: It was evident that full traction on middle lobe through small anterior thoracotomy wound did not render root of this lobe extra thoracic. In other words, amputation of a lobe by anterior approach with small opening did not remove all of the lung tissue of that lobe. A posterior attack was undertaken. Simple thoracotomy for technique was first attempted.

Aug. 24, 1907: Brindle-pup, long ears, long legs; weight 24 pounds. Dog etherized on back, then turned to prone position on board. Cone and apparatus adjusted readily by placing chin rest under lower jaw. Shaving of coarse hair of back more difficult. Preparation otherwise the same. Semicircular flap as near scapula as possible, exposing muscle over second and third ribs. Muscle external to erector spinæ group (corresponding to trapezius and latissimus fibres) divided transversely. Rib excised as in ventral operation. Wound sutured in layers by usual gridiron method.

Aug. 15: Condition good. Appeared normal in all respects. Respirations 30.

Aug. 20: Chart normal. Temperature 102; pulse 100; respirations 20.

Aug. 22: Skin stitch parted for distance of 2 inches. No infection. Secondary suture, with wick remaining.

Aug. 27: Secondary skin suture suppurating, but considerable gain has resulted from attempt.

Sept. 2: Distemper symptoms. Dog in room previously occupied by Case XV, with distemper. Food taken well. Pus from eyes and nose. Diarrhoea.

Sept. 19: Fell out two story window and broke femur of right hind leg. Swelling appeared under operation flap.

Sept. 21: Five weeks since operation. Dog killed with ether on account of broken leg.

*Autopsy*.—One ounce of sero-hemorrhagic fluid allowed to escape from under skin flaps. Focus of origin traced down to pocket between intercostal and pectoral muscle layers. Finger introduced in 5th intercostal space, and both internal and external surfaces of pleurotomy wound examined bimanually. There were no adhesions on pleural surfaces, and the pleurotomy scar was solid, pale in color, with silk stitch enclosed in cicatrix. Both lungs and pleural cavities normal.

CASE XVIII.—Operation: *Dorsal pleurotomy, with pneumectomy of left lower lobe*. Result: *Death*. Object: Dorsal thoracotomy evidently successful. Object to try dorsal approach to lung root.

Aug. 15, 1907: Bull terrier bitch (black and white); weight 18 pounds. Technique of thoracotomy the same. Lower left lobe withdrawn from cavity with difficulty, owing to the large presenting posterior surface,

which was with difficulty dragged backward through opening. No gain in extra thoracic approach to root. Lobe could not be withdrawn far enough to apply clamp extra thoracically to the main vessel trunks. This might have been possible through a large pleural opening. Clamp applied one inch from hilum. Lobe amputated. Two large orifices in stump tied separately (probably artery and bronchus). Continuous to stump followed by transfixation and ligature proximal to clamp. Considerable difficulty in closing stump even with two rows of sutures.

Aug. 15: Apathetic. Pulse 160; respirations 36.

Aug. 16: Refuses milk and solid food.

Aug. 17: Temperature 103.4; pulse 150; respirations 48.

Aug. 19: Slight dullness of operated chest. Temperature 103.2; pulse 178; respirations 35. Lying down and lacks energy to shake flies from head and nostrils, from which there is a profuse purulent discharge, somewhat more marked on left side.

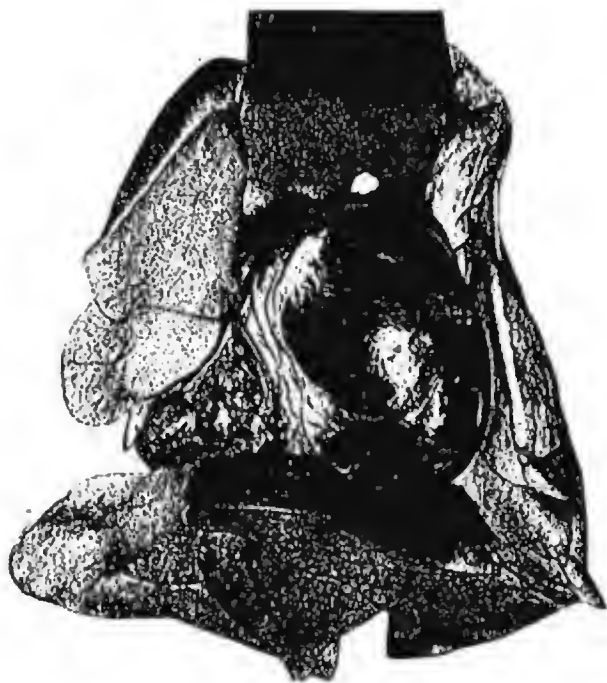
Aug. 21: Dullness of left chest approaching flatness. Skin wound clean, dry and flat. Dog placed on board. Etherized. One-half inch of 7th rib excised. Finger introduced. Lung found retracted over all pleural surfaces. Vacuum pump connected with glass funnel, which was placed over wound snug to skin. Probably about six to eight ounces of hemorrhagic purulent fluid sucked into conduit. Water introduced and sucked out again repeatedly. Two drainage tubes inserted and pinned into place. Evidently dog was suffering from general pleuritis of left cavity, although right lung seemed to be doing sufficient work by an increase of respiratory movements. The pneumothorax now produced was no added evil, in so much as the lung was found already retracted and adherent. Mediastinum was also thickened and more stationary.

Aug. 24: Dog lived 3 days after drainage, but condition did not improve. Pulse remained over 160, and it was of interest to note that temperature was normal on day of drainage.

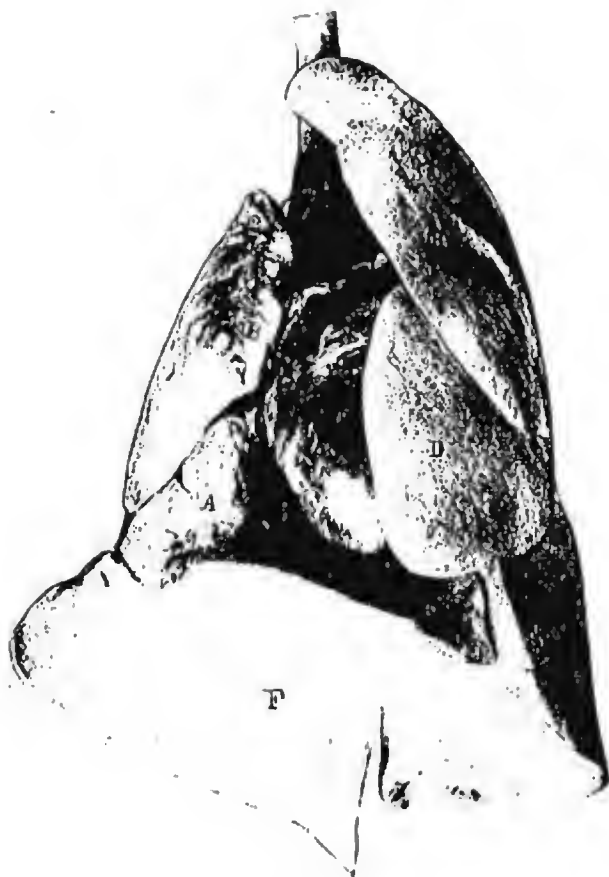
Died. Placed in cold storage to await autopsy. By mistake of janitor this animal was destroyed before autopsy. Judging from findings in similar cases, it is probable that the unopened chest was also infected, and death was due to infection of both pleural cavities.

CASE XIX.—Operation: *Anterior thoracotomy, excision of right middle lobe.* Result: *Recovery.* Object: Evident that with a larger pleural opening as much can be accomplished extra thoracically by anterior as by posterior approach. It is also possible thus to avoid the difficult skin preparation, the turning over of the animal, the less adapted musculature, and the difficult withdrawal of the lobes, from the base, rather than the apex of a cone, as it were.

An attempt was also made in this experiment to reduce the air-leakage through the pleural opening during the stump suture. The object in this being to, first, reduce the loss of body heat which is ever present in the sucking in and out of outside air into the pleural cavity; second, to lessen also the chance of infectious particles being sucked into the cavity at the same time; third, to diminish the amount of positive pressure necessary to prevent collapse; in other words, to avoid pneu-



CASE XIX.—Excision right middle lobe. (A) Stump.



CASE XX.—Excision of one-half of right upper and middle lobes. (A) Stump of middle lobe. (B) Stump of upper lobe. (C) Left upper lobe. (D) Left middle lobe. (E) Left lower lobe. (F) Diaphragmatic surface of lower lobes.

mothorax as nearly as possible without the help of the apparatus; fourth, to diminish the fluttering tendency of the mediastinum towards the opened side at expiration, and thus to avoid injury to the latter.

Simple packing of gauze around the clamp, owing to the constant movements of the ribs, is not only difficult to maintain, but at the same time permeable. A "stump controller" to be later described served the above purpose admirably, and offered the additional advantage of holding the stump and clamp in fixed position, thus making a more careful approximation of pleural edges in the stump suture.

It was also concluded that picking up and tying of all passages and blood vessels in the stump might, if followed by accurate closure, avoid the necessity of transfixation.

Aug. 20, 1907: Black and white bull-dog; weight 22½ pounds.

Original technique of thoracotomy with excision of 2 inches of 5th rib. Middle lobe drawn out to full traction. Clamp applied. Stump controller applied; gauze packed tight between its under surface and the pleural opening.

Every visible opening in stump snapped and tied with Von Brun linen. Two rows of linen to stump. First row deep; second to pleura only. Clamp released gradually. No oozing or leakage from stump. Wall suture gave satisfactory approximation.

To be noted here that during two-thirds of this operation animal was breathing against only 1-2 cm. of water resistance, as a result of the reduced pleural opening.

Aug. 22: No apparent change in dog's condition. Appears and acts as before operation. Solid food taken ravenously. Temperature 100; pulse 115; respirations 28.

Aug. 25: No change.

Aug. 31: Stitches removed; wound clean and dry.

Sept. 5: No symptoms have developed. Chart has remained normal.

Sept. 30: Dog has developed mange, which causes no symptoms but loss of weight.

Oct. 20: Since last note dog has continued well, with exception of intercurrent mange.

*Autopsy*, Oct. 20.—Dog killed with ether. One light adhesion between middle lobe stump and pleurotomy wound. Adhesions in immediate vicinity of stump readily separated. Pleural cavities both normal. Lung tissues apparently normal. Lungs and heart excised, inflated and photographed.

CASE XX.—Operation: *Anterior excision of one-half upper and middle lobes*. Result: *Recovery*. Object: Satisfied that anterior technique is perfected and necessary in amputation of middle lobe attempted more extensive pneumectomy.

Aug. 25, 1907: Airdale-terrier mongrel. Long hair removed. Increased chance of sepsis from neighborhood of prepared area. Normal method of entrance. Pectoralis cut more tangentially to line of ribs, increasing gridiron arrangement. Middle lobe drawn well out of wound and clamped. Controller applied. Amputation. Bronchus and vessels

in immediate vicinity in stump ligated in single tie. Continuous to and fro linen stump suture. No transfixation or ligation of stump. Upper lobe withdrawn to half its extent and treated in identical manner. Very slight bloody ooze in region of stumps when dropped back. A tear occurred in first row of pleural stitch, which was closed by second row.

During operation 2-3 cm. (water) pressure sufficient to maintain rhythmical respiration during treatment of stumps. Animal kept light under ether. Time 2 hours. Aug. 26: dog not visited

Aug. 28: Condition excellent. Temperature 102; pulse 126; respirations 35. Hot day accounts for rapid respiration, which is not labored. Prognosis is good. As in question of peritonitis, third day seems to settle prognosis. Dog presents none of serious symptoms which fatalities without exception have manifested on the third day.

Sept. 5th: Prognosis of last note proved correct. Eating well. Active.

Sept. 12th: Stitch, left in as experiment, was not aseptic. Removed.

Oct. 25th: Since last note this dog has been normal in appearance, habits and actions. On several occasions he was heard to give a low cough.

*Autopsy* (lapse of eight weeks since operation).—Killed with ether. No adhesions at any point between visceral and parietal pleurae. Light adhesions between stumps of middle and upper lobes. Half of each of these two lobes found lacking. Heart and lungs excised in toto, and frozen. Four weeks later inflated and photographed as in photograph (C).

It will be noted from the above that of 15 cases, including six simple anterior thoracotomies and 9 excisions of portions of lung tissue, Cases I and V were the only fatalities. It is fair to explain these two deaths on the basis of undeveloped sepsis and technique existing at the beginning of this series of operations.

On September first, in view of the low mortality, I had become entirely confident of being able to do simple thoracotomy with surety of recovery. I was sure also of recovery after excision of either upper or middle lobes, or portions of either or both.

Departures from the one-rib-excision technique had not been successful. The only case of lower lobe excision had ended fatally, although it was done by the less perfected posterior approach. The only attempt made in a three-lobe excision had also resulted in death.

The number of recoveries after thoracotomies and moderate excisions convinced me that these fatalities were due

neither to serious influences of the positive pressure method, nor to the existence of pneumothorax at the end of the operation, inasmuch as these factors, had they not been successfully avoided, would likewise have caused death in a majority of the above recoveries. The history of the surgery of the lung reveals rare isolated cases of total extirpation of one normal lung without thoracoplasty with recovery. We also recognize clinically that numerous cases are known to have lived a number of years with only a small portion of the total lung volume remaining functional. It is, therefore, to be presupposed that the above fatalities, and those of extensive resections which may later occur, cannot be explained on the basis of the loss of aerating lung tissue.

As regards sepsis, it must be admitted that in more extensive lung resections there is greater opportunity for infection, because such operations are of longer duration, thus favoring the entrance of sepsis from the normal channels, such as instrumentation, sucking in of infectious air particles, and prolonged exposure of the lung stump. On the other hand, the above sequence of 14 cases (VI-XX) with only three deaths, two of which were the two cases above referred to, that of excision of lower lobe and that of total extirpation, leads me to infer that my aseptic technique is reasonably reliable in animal experimentation, and that the explanation of sepsis in these two cases, and also in those which may later follow of extensive resections, must be found in one of the following factors:

1. The improper closure of the stump with leakage of infectious material.
2. Insufficient closure of stump leading to escape of air, resulting in pneumothorax and collapse, which were not present at the end of operation.
3. Perhaps to the establishment of a definite cavity which may be filled either by granulations or compensatory emphysematous displacement of the remaining lobes.

CASE XXI.—Operation: *Excision of right lower lobe.* Result: *Death in three days.* Cause: *Sepsis: pneumothorax from leakage of*

*stump.* Object: To attempt a series of more extensive lung resections.

Sept. 1st, 1907: Brown and gray mongrel. One rib thoracotomy. Lower lobe withdrawn to limit of traction. Clamp (unprotected) applied extra-thoracic. Amputation. All vessels and bronchioles in stump tied separately. Same used to pick up each vessel in sequence. Attempt then made to concave lung stump with use of thermo-cautery. (Necessary break in asepsis here, after which hands were hastily passed through sterile water and alcohol.) Object of concaving stump was to allow better approximation of pleural edges with possibility of inversion. First row of linen continuous to stump included the latter; a second row of continuous taken deeper and needle was felt to pierce the linen ligatures in the stump. When stump was dropped back after removal of controller, there was a tendency to dyspnoic breathing which was at once relieved by placing palm of hand over wound until normal rhythmic respirations were restored.

Gridiron suture of thorax wall same as in recent cases described. The pleura-intercostal layer was not tight, however, owing to diagonal tears at ends of the wound caused by withdrawal of large lower lobe through an insufficient pleurotomy incision. The pectoral muscle layer, however, seemed to render closure hermetical.

Sept. 2: Chart starts poorly. Temperature 104; pulse 163. Languid.

Sept. 3: Weakness suggested by tottering gait; pulse 170; respirations 38; temperature 102.6; prognosis poor.

Sept. 4: Dog found dead at 9.30 A.M. Died some time during night, but rigor was not well marked.

*Autopsy* at 11 A.M.—All layers of wall apparently undisturbed. Beginning healing. Three ounces of sero-hemorrhagic fluid in left side. Left lung normal in structure. Right lung upper and middle lobes somewhat atelectatic, and covered with fibrinous exudate. Stump of lower lobe found buried in lymph and fibrin. Suture in place, but pleural edges were everted. On inflation air escaped through an opening in stump  $\frac{1}{4}$  inch in diameter. When stump suture was removed, stump lay open again to boat-shape produced by cautery. At bottom of boat was an accumulation of pus.

*Conclusions.*—Septic fibrinous pleurisy. I believe that suppuration came either by introduced bacteria or by infection from the lung stump (which is suggested by the buried pus below the line of suture), which led to sloughing of the stump and liberation of ligated air vessels, and consequent pneumothorax and collapse of lung.

CASE XXII.—Operation: *Excision of three right lobes.* Result: *Death in 5 days.* Cause: *Septic pleurisy; pneumothorax.* Object: To attempt removal of three lobes.

Sept. 2, 1907: Fox-terrier, brown and white; weight 21 pounds. Not known at the time that result of Case XXI was to be fatal. Apparatus fairly satisfactory, but pressure seemed insufficient when pleural opening was unoccupied. Middle lobe amputated as usual, except that boat-shape of stump was this time produced with scissors, previous to tying off vessel openings. Excessive traction on clamp caused lateral



tear in lung tissue proximal to clamp (not closed). Lower lobe clamped transversely to wound, and controller well packed with gauze. Five minutes later, on looking into cavity, air could be seen bubbling through small accumulation of blood around stumps. Leakage evident but trusted to clotting and adhesions to stop it. Upper lobe amputated and concaved with thermo-cantery.

Sponge used to pack off mediastinum removed and found soaked with blood. Mediastinum presented very slight tear. Pleura torn towards axillary rib stump. First row of sutures, however, rendered wound solid. Temperature after operation 96. Afternoon of operation, dog normal and active.

Sept. 3rd: Dressing had been scratched off. Clean one applied. Chart good. Temperature 102; pulse 122; respirations 20.

Sept. 4th: Dog wags tail but disinclined to stand. Took 3 ounces of milk.

Sept. 5th: Condition worse. Languid. Respirations short, more rapid, with slight "grunt" at end of a forced expiration. Temperature 103.6; pulse 150; respirations 38.

Sept. 6th: Respirations more labored. Right chest dull with areas of flatness. Animal placed on board. Opening made through centre of flap. Pus encountered at once under skin with free opening below to pleural cavity. Vacuum pump with funnel attachment applied air-tightly over wound. Hemorrhagic fluid loaded with fibrin sucked away to amount of perhaps six ounces. Meanwhile dog under positive pressure apparatus to aid in the expansion of the sound lung by preventing the deviation of the mediastinum towards the unopened sound chest. Breathing seemed more regular and less labored, with help of this combined positive and negative pressure action. Continued for one-half hour. Drainage tube introduced and stitched close. Gauze dressing and rubber dam superposed with hope of obtaining the suction claimed for the A. T. Cabot empyema dressing. Hair over skin surrounding wound prevented the air-tight approximation of rubber to skin, thus ruining the purpose of the dressing. Swathe applied snugly for 1½ hours. No improvement in condition. Placed on table again. Suction applied 20 minutes; object to support the mediastinum and prevent limited expansion of the sound lung. Then suction and positive pressure both for 1½ hours. Dog considerably weakened by this manipulation. Sat up to ease respiratory movements, but weakness would cause him to fall again.

Sept. 7th: Dog found dead following morning, having been two days in special laboratory cage with flannel blanket covering swathe to increase body heat.

*Autopsy.*—Very little fluid remaining in right chest. Right lung stump collapsed and covered by homogeneous flat surface of thick fibrinous exudate, which extended from the lung root to the pericardium and mediastinum, making these several structures scarcely distinguishable. On inflating lungs no leakage was detected from any of the three stumps, although it is quite possible that this was prevented by the adherent exudate.

CASE XXIII.—Operation: *Intercostal pleurotomy*. Result: *Recovery*. Object: To test the technique of opening cavity without rib excision, as recommended by Mienliez with use of a rib-spreader.

Sept. 2, 1907: White fox-terrier. Gridiron incision as pictured in drawing II. Spreader used in mastoid operations utilized as shown in drawing III. Ample room thus obtained for excisions. Lung not disturbed. Wall suture in layers.

Sept. 3: Condition excellent.

Sept. 10: No change in condition.

CASE XXIV.—Operation: *Excision of three lobes (right)*. Result: *Death*. Cause: *Pleuritic effusion. Collapse of lung*. Object: The fate of Cases XXI and XXII was not concluded when this operation was attempted. Had it been so another lower lobe excision would have been attempted previous to this total extirpation. The main object of the operation was to test the suitability of an intercostal pleurotomy without rib excision, for the extra-thoracic removal of one or all lobes of the lung.

Sept. 3, 1907: Large black and white bitch; weight 20 pounds. The skin incision was made in the form of a long tongue shaped flap with apex near median line over the 5th intercostal space. Muscles and fascia over intercostals divided. Intercostals divided midway in line parallel with curve of ribs. Pleura and intercostal fascia in same line. Ribs then separated by means of a spreader as shown in drawing II. With latter in place, respirations became somewhat labored until pressure was raised to 8 cm. (water). Less was required, however, when opening was occupied by extracted lobes with packing of gauze.

Upper and middle lobes withdrawn, and removed as in the previous operation. Tying of numerous separate openings in stumps was rather unsatisfactory, and the need of an assistant was most evident. Difficulty met in removing lower lobe, not from lack of spread in thorax opening, but rather in deficient length of incision. Resistance to pressure side-tracked in apparatus allowing momentary collapse, and thus enabling easy withdrawal of lower lobe which was clamped as near hilum as possible. The time required for careful treatment of stump was not thought advisable, and a chance was taken on single ligature, with three strands of fine Von Brun linen (a most unsuitable material for such purpose). When stump was dropped back, fresh blood was seen coming from cavity. Inspection of lower lobe stump revealed no leakage, however. Fingers introduced to base of cavity, where blood clots were found. Preferred not to exert traction again on upper stumps, so clotting and absorption were relied upon, inasmuch as there was little possibility that bleeding was from main trunks.

Pleural stitch satisfactory, although it was difficult to pick up the retracted pleura from under the intercostal stumps, as stitch approached completion.

Sept. 4th: Dog apathetic. Hacking cough at times. Chart fairly satisfactory. Temperature 100.6, subnormal; pulse 135; respirations 34.

Sept. 5th: Respiration higher (48). Food taken reluctantly.

Sept. 6th: Lying down. Prognosis poor. Right chest flat to percussion. Respirations 60; temperature 104; pulse 120. No food taken to-day.

Sept. 8th: Entered recovery room to see the dog take last three breaths.

*Autopsy* 30 minutes later.—Skin wound covered with thin layer of dried blood. Muscle apposition solid, and union commenced. Positive pressure apparatus applied and water sprinkled over wound. There was no bubbling of air through the latter. In removal of right chest wall numerous transparent adhesions were found spanning from parietal pleura to root of lung, namely to the lobe stumps. There were similar bridges to the diaphragm. Right pleural cavity completely filled with hemorrhagic fluid, at bottom of which were no free clots or sediment. (Culture.) This fluid contained no fibrin or pus, and was evidently transudate. Left chest opened. Left lung normal. No blood or fluid in left cavity.

Thoracic contents excised in toto. On examination of remainder of right lung, it was found that all had been removed with exception of a quadrangle shaped fragment, evidently the stump of the upper lobe, which was dark purple in color, but covered by shiny serous coat. The pleural edges had evidently been successfully inverted, but the sub-pleural hemorrhagic condition indicated incomplete tying of vessels in the stump, which may have been responsible for the ooze during remainder of operation. The stump of lower lobe, which had been ligated only, was covered by a dark blood clot. The ligature was in place, and not perceptibly loosened. Under pressure greater than required for the complete inflation of the sound remaining lung, an escape of air was detected at pin point opening in the ligated stump. The heart was apparently not displaced.

CASE XXV.—Operation: *Excision of right lower lobe.* Result: *Death.* Object: Removal of upper lobes has been successful. Removal of all lobes has been fatal. Question arose then whether the removal of lower lobe was responsible for death.

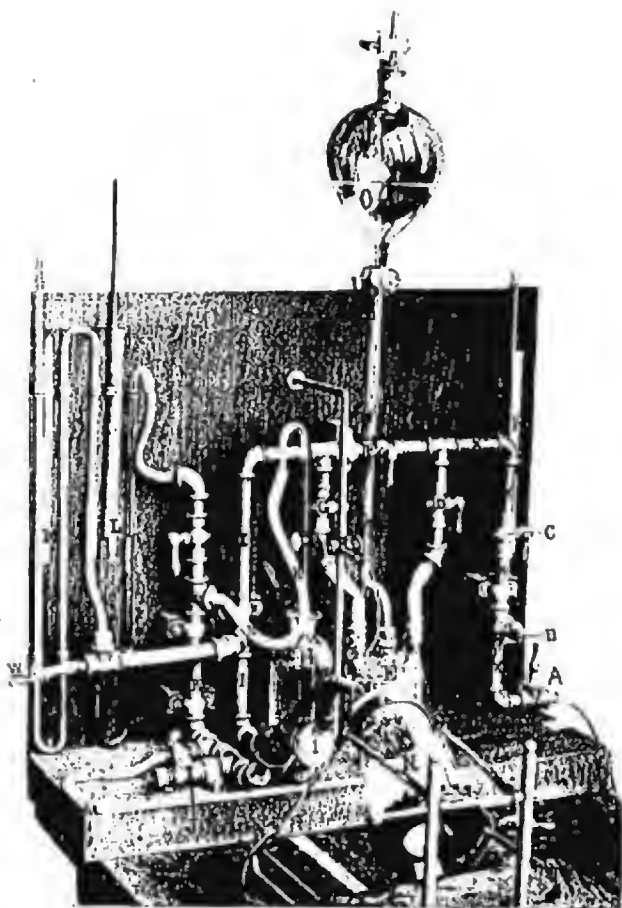
Sept. 10, 1907: Fox-terrier; bull-terrier mongrel. Right intercostal pleurotomy. Spreader introduced. Lower lobe clamped and amputated. Stump concaved. Vessels and bronchioles tied with especial care. Braided pedicle silk then placed proximal to clamp and drawn tight. At this moment a joint in a rubber tubing air conduit parted before second knot of ligature was taken. Stump dropped back, and gauze stuffed into wound. Respirations immediately became labored and intermittent. Tubing repaired with difficulty, but in time to prevent death. Stump withdrawn again for second knot in ligature. Wall sutures applied as usual. Rectal temperature at end of operation, below 96.

Sept. 10, 11 A.M.: Dog found dead; still warm. *Autopsy* one hour later. Wall sutures solid and clean. Right chest was half full of sero-hemorrhagic fluid (culture on blood-serum). Lower lobe found to have three lobules, one of which only was removed. Adhesions between stump and diaphragm. Lower lobe stump bulging at centre, but there was no

leakage under inflation. All remaining lobes of right lung normal. No atelectatic areas. Left lung normal. No fluid in left chest.

Cases XIII, XVIII, XXI, XXIV and XXV constitute a group of fatalities which should be considered together. In three of these cases a lower lobe was removed. In three other all of the right lobes were removed. What was the cause of death in these cases? I am tempted, at the outset, to exclude the use of positive pressure apparatus as the cause of fatality, and to credit deaths to the existence of a permanent cavity remaining in the right chest after operation. Even in the presence of sepsis, which existed without question in three of these cases, the principal cause of death was undoubtedly the effect of the presence of a cavity in which the air pressure did not equalize that of the unopened side of the chest. Such a difference must necessarily lead to the deviation of the mediastinum towards the remaining lung during inspiration and away from it at expiration. Such movements must hamper the excursion of the remaining lung, and restrict its oxygenation. The persistence of this undoubtedly causes circulatory disturbances by its effect on the right heart. Just what these disturbances are will be discussed in a later paper. The postmortem cultures taken in these cases were not under strictly aseptic precautions, and I have excluded them in the case reports. The operations were done under the same aseptic procedures. The increased possibility of sepsis caused by the increased length of operation, and added exposure of the lung stumps, are not sufficiently important factors to explain the cause of death in this group of cases, especially since the previous operations, with one or two exceptions, were absolutely free from pleural infection.

With a further desire to practically test this question, renewed efforts were made to exclude all chances of infection, and to rule out any possibility of leakage through the lung stumps which will of course produce pneumothorax, with resulting compression of the sound lung.



PHOTOGRAPH A.—Positive pressure apparatus.

## DESCRIPTION OF APPARATUS.

The glass cone (N), with a rubber drum over the base is placed over dog's face, the drum causing air-tight closure just forward over the eyes. Thus any possibility of constriction around the neck is avoided. The cone is held in position by side straps, as shown in photograph. Compressed air enters the apparatus at A. With pet-cock B opened and cock C closed, manometer P is read. Experience teaches how much pressure with vent B open is suitable before leading air through apparatus. Cock C is now opened, and B closed. Air passes along conduit X, X, X. With cocks adjusted as in photograph, air passes through D into ether bottle, E, and out again through G. By pipes I, I, I, it enters cone and at inspiration passes into lungs. Dog's snout fills up most of cone, so that small dead space exists and exhaled air passes immediately through efferent conduit K, K, K to water column H. By raising or lowering clamp R on upright rod, the resistance to pressure is varied. Such resistance is indicated in water manometer L and mercury manometer M. Previous to pleurotomy pressure may be avoided without shutting off or side-tracking air compression by opening cock, which allows almost immediate exhaust to exhaled air. Through cock to the vacuum the resistance is recorded through glass conduit to foot of table, where it connects with tambour and is recorded on revolving drum. Tubing (W) is connected with oxygen tank, which on closure of cocks F and G substitutes oxygen for compressed air and manometer M gives reading of oxygen pressure.

From reservoir O, ether may be added at any time to bottle E, with cock F open and D and G closed.

If more air is desired for dilution of ether-vapor, cocks F, D and G are left open. If air alone is desired F is left open, and D and G closed. At point J may be seen piece of rubber tubing slipped over cock such as are boiled with instruments and placed over cocks B, C, F, G, D, and J just previous to incision, so that operator can control apparatus without breaking asepsis.

CASE XXVI.—Operation: *Excision right lower lobe.* Result: *Recovery.* Object: With renewed possibility of asepsis of perfected apparatus, another lower lobe excision attempted.

Sept. 15, 1907: Black pointed nose mongrel; weight 25 pounds. Long tongue shaped skin flap with apex one inch from median line, base in axilla. Fifth intercostal space incised three inches. Lower lobe readily withdrawn through this increased opening. Technique improved by use of Doyen clamp, with blades protected with rubber tubing (see drawing IV). With this long clamp transverse to ribs, with gauze packing around stump, immobilization was accomplished without use of stump-controller. Stump treated with greatest possible care. Concaved to boat shape. All vessels searched out and tied. New technique of closure employed as described in drawing (V). Inversion of pleural edges by the Lembert suture most satisfactory. In every previous case lung tissue has presented along suture line between stitches. Stump dropped back, with no oozing of stump on removal of clamp. In pleuro-

intercostal continuous linen stitch, all turns were taken before any one was drawn tight, thus allowing the natural gaping of the wound to persist until needle work was complete. In this way pleural edges could be clearly seen and picked up at each turn. Two sutures were used, each beginning at either end of wound and working toward the centre. When placed the turns of one stitch were taken up consecutively, and tied. Those of the second stitch were similarly taken up, beginning at the end of the wound and working towards the centre. The latter stitch was not tied until an excessive resistance to pressure had been applied at end of expiration, thus evacuating as much air as possible from the pleural cavity before final closure was secured. No vessels in the thoracic wall were tied in this case. Continuous over and over linen stitch to skin. Quick recovery from ether, with no respiratory disturbances.

Sept. 16: Somewhat subdued, but wagging tail and able to jump down from bench. Temperature 101.6; pulse 140; respirations 30-40.

Sept. 17: Respirations panting, due to heat of day.

Sept. 20: Accumulation of fluid under skin flap led me to fear that there was connection with pleuritic effusion. Chest aspirated in axillary line, and suction employed, but no fluid was obtained. It was evident that motion had occurred between muscle layers, allowing, as in all such cases, an accumulation of fluid outside the fascia. This was allowed to escape from under the flap.

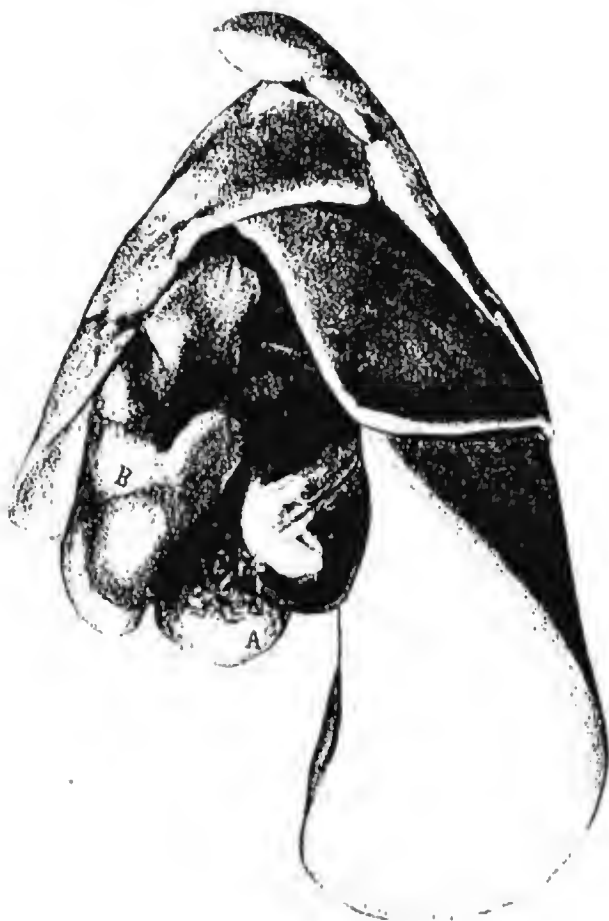
Sept. 24: Dog entirely well. Stitches all out. Active and eating well. Shows no evidence of operation.

Oct. 25: Well since last note. No symptoms. Has gained about 4 pounds in weight.

*Autopsy*, Nov. 13, 1907.—Dog entirely well. Killed with ether. Pleural cavity opened in 6th space. Finger introduced for palpation of pleural surface of original thoracotomy wound. There were no adhesions, and the line of pleurotomy could not be distinguished owing to its serous covering. Lungs and heart removed in toto. Right chest wall removed. There were no adhesions between visceral and parietal pleurae at any point. Both pleural cavities fluid free, and normal in appearance. Heart not displaced. Lungs and heart removed in toto and inflated with apparatus, a cut being allowed in conduit regulated to keep lung at a given stage of inflation. The lung tissue appeared to be normal throughout. Numerous easily separated adhesions between lower lobe stump and adjacent surfaces of middle lobe and mediastinal or "butterfly" lobe. The middle lobe as a result of these adhesions had assumed a cabbage-like appearance. ( See Photograph E.)

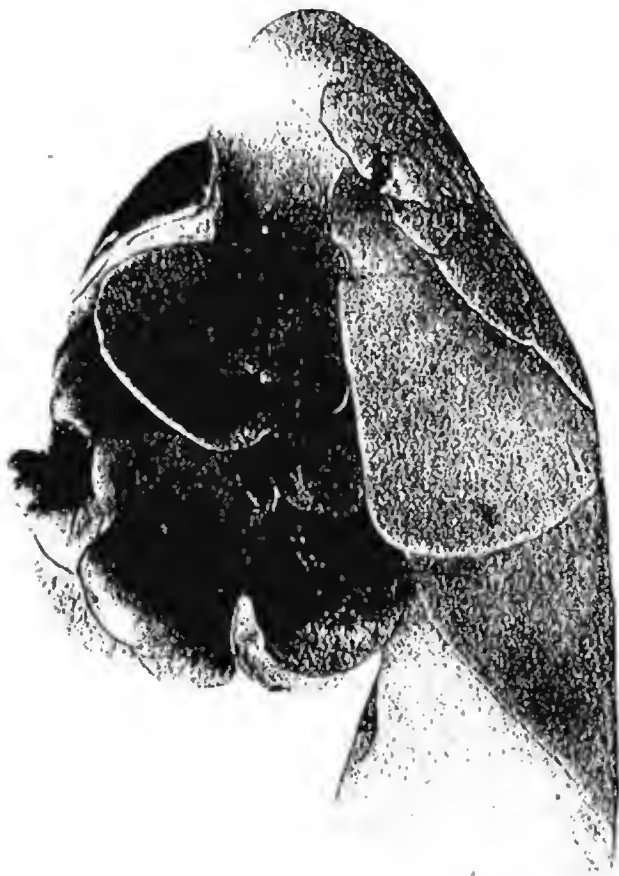
CASE XXVII.—Operation: *Pleurotomy*. *Clamping and release of right lower lobe*. Result: *Recovery*. Object: Apparent good progress of Case XXV encouraged me to attempt second lower lobe excision with new apparatus.

Sept. 16, 1907: Boston terrier—bull terrier mongrel; weight 26 pounds. All sterile arrangements completed when ether cone slipped from its attachment. Asepsis broken in reapplication, also possibility of infection of sterile rubber protection tubing on two of valve cocks.



CASH XXVI a.—Excision right lower lobe. (A) Stump. (B) Right middle lobe.





CASE XXVI b.—Excision right lower lobe, (A) Stump. (C) Mediastinal lobe turned upwards, (B) Right middle lobe.

Laparotomy sheet slid downwards during these manoeuvres, and incision was consequently made by mistake in seventh intercostal space. Soon evident that withdrawal of lower lobe would be difficult through this space. Under full traction only about three-fourths of lobe could be withdrawn, necessitating a large stump which would be difficult to close tight. Rather than run the risk of a mortality under these conditions, the "stomach-clamp" which had been applied was, after five minutes' application, removed. Considerable manipulation of the lung had thus occurred. At one moment of manipulation pulse beats suddenly became very slow, and respiration nearly ceased. When lobe was released, both functions were restored to normal without change in pressure. This was doubtless due to irritation of vagus terminals. (See changes at this stage of operation in tracing. In spite of considerable trauma to lower lobe, after which hemorrhagic areas were apparent as well as small atelectatic areas, I concluded to attempt recovery in this case, thus to test the resistance of normal lung tissue to such manipulation. Thorax wall sutured in layers, as in Case XXV. Time one hour.

Sept. 17, 1907: Dog as lively as before operation. Showed no signs or symptoms of any sort. Temperature 102; pulse 140; respirations 24.

Sept. 18: Temperature 102; pulse 92; respirations 20.

Sept. 20: Dressing removed. Wound clean and dry. Chart and notes omitted.

Nov. 15: There has been no interruption to normal convalescence.

*Autopsy.*—Dog killed with ether. The thorax well showed strong cicatrization of all layers which were adherent to one another. There was no fluid in either pleural cavity. There was one small light adhesion between the inferior surface of the right lower lobe, and the diaphragm. The contour of the right lower lobe was normal throughout. There were no hemorrhagic, emphysematous, or atelectatic areas at any point, and the parenchyma presented a normal homogenous pink coloration. In other words, there was no evidence that the lower lobe had ever been under clamp compression.

CASE XXVIII.—Operation: *Total excision of right lower lobe.* Result: *Recovery.* Object: To further test the effect of pneumectomy of a lower lobe.

Sept. 20, 1907: Fox-terrier (brindle spots); weight 18 pounds. Technique of this operation was identical with that of Case XXV. Visceral pleura incised annularly  $\frac{1}{2}$  inch from clamp, and attempt made to roll it back to form a pleural cuff. This was partially successful, although pleura, being incorporated in lung parenchyma, required some dissection for its separation. Two rows of inverting Lembert sutures were thus easily and successfully taken.

This operation was most satisfactory in that each step of the technique was successfully carried out, and the mechanism of the new apparatus was excellent.

Sept. 21: Dog languid and not inclined to eat. Prognosis poor.

Sept. 22: Temperature 103.6; pulse 170; respirations 60. Dog seemed "sick unto death." Pleuritic effusion feared. Chest aspirated in axillary line, 7th space. No fluid obtained.

Sept. 23: No improvement, except in respirations (48). Refused food. Characteristic hitch at end of short expiration present in previous fatal cases.

Sept. 24: Able to hop down from bench. No food taken. Drainage had been so unsuccessful in above fatalities that I preferred to wait. The following day dog began gradually to take a turn for the better. Food taken with considerable hand-to-mouth coaxing. Dog walking about and looking better.

Sept. 27: Temperature 103.6; pulse 160; respirations 30. Wound clean and dry.

Sept. 30: Temperature 102.4; pulse 110; respirations 22. Dog much improved. Peculiar action of hind legs noted. Dog cannot jump without falling. Apparent weakness beyond lumbar spine. Hind legs cross in walking, and a tottering gait is noted.

Oct. 25: Dog has gained weight and eats well. Spastic action of lips and legs persists.

Nov. 10: There is a slight kyphosis in lumbar region, and a deep skin ulceration in same region one-half inch from vertebral column.

*Autopsy*, Nov. 13, 1907.—General condition excellent. Dog etherized. Anterior neck dissected and trachea freed. Trachea clamped at end of inspiration and cut. Object of this was to determine the exact size and condition of the cavity left by lower lobe excision previous to post-mortem collapse of lungs.

Portion of lower right chest wall removed. Remaining lobes of right lung found in close apposition to parietes, indicating normal inflation. Vacated space was not filled by compensatory dilation of remaining lobes, nor by heart displacement, nor by an accumulation of fluid. Unlike Case XXV, however, the space was about half filled with peculiar looking material resembling lymph in texture, but of a reddish color. It seemed to arise from all pleural surfaces which bounded the space previously occupied by the lower lobe. With a finger it could be wiped away from these surfaces without difficulty.

Lungs and heart excised in toto. Stump of lower lobe firmly adherent to diaphragm, middle lobe, mediastinal lobe and pericardium. These adhesions were freed with some difficulty.

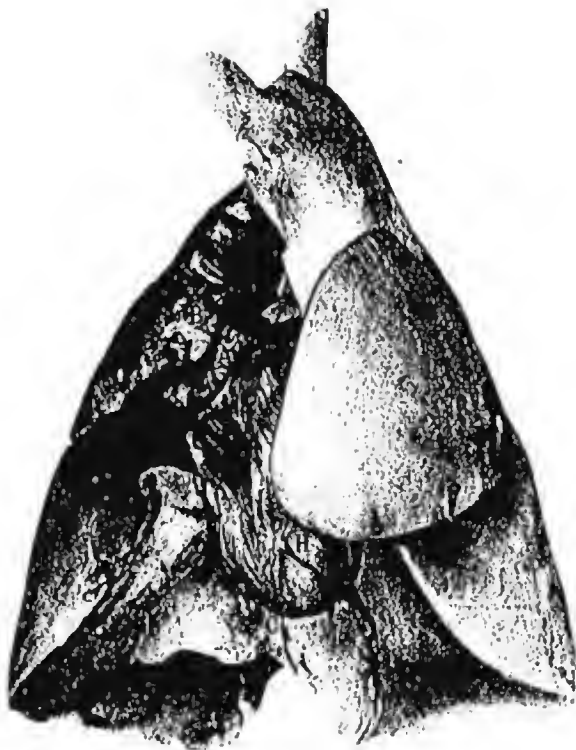
Tissue examined by Wolbach proves to be free granulations.

CASE XXIX.—*Operation: Imitation of an exploratory operation for tuberculosis, with removal of two isolated foci.* Result: *Recovery.* Object: While watching prognosis of Cases XXVI and XXVIII to do a less radical operation.

Sept. 22, 1907: Large black bull mongrel; weight 26 pounds. Incision triangular in shape, with apex towards median line. Apparatus satisfactory throughout operation. Found it advantageous to increase pressure more by added influx of compressed air and less by sinking glass tube in water column. In other words, increased compression with



CASE XXVIII.—Excision of right lower lobe. (A) Stump. (B) Right middle lobe. (C) Left lower lobe. (H) Heart.



CASE XXX.—Excision of right upper and middle lobes. (A) Stump of middle lobe. (B) Stump of upper lobe. (C) Mediastine on butterfly lobe.

diminished resistance resulting in the same manometer readings as in the reversed conditions.

Right upper lobe withdrawn and handled roughly. Doyen clamp applied two inches distal to root extra-thoracic. An oval shaped fragment the size of an almond was then excised from internal surface of lobe. Three ties taken in wound thus made. Bared surfaces approximated with linen and an inverting of pleural surfaces accomplished. Middle lobe then withdrawn and clamped. A triangular shaped piece with sides  $1\frac{1}{2}$  inches long then amputated from the tongue of this lobe. Usual treatment of stump. Lower lobe not disturbed.

Sept. 23: Dog very lively, as before operation. Solid food at once.

Oct. 14: There has been no change in this dog's condition. He has gained weight, and is active as usual.

Dec. 8: Dog has been a good laboratory animal, and has been kept for physiological tracings during autopsy.

CASE XXX.—Operation: *Amputation of upper and middle lobes (right)*. Result: *Recovery*. Object: To repeat an amputation of upper and middle lobe as in Case XX, where, as will be seen in photograph, scarcely more than half of these lobes had been amputated. With new intercostal technique and use of spreader, more complete pneumectomy could undoubtedly be performed.

Sept. 27, 1907: Black pointed-nose mongrel. Usual technique of last few cases with new apparatus employed. The advantages of the new apparatus are most gratifying. The control is simple, the conduits are wide, the connections are solid, and I am entirely satisfied of its practicability.

Sept. 28: Very slight languor. Solid food taken day after operation.

Sept. 30: Normal chart: Temperature 102.2; pulse 75; respirations 20.

Nov. 20: This dog's convalescence has been absolutely uninterrupted.

*Autopsy*.—Dog killed with ether. No fluid in either cavity. Microscopically parenchyma of both lungs normal. Stumps of middle and upper lobes adherent to one another, with adhesion also to upper surface of lower lobe. These adhesions were freed, and the lungs and heart excised and photographed.

Pieces of lung stumps placed in Zencke's fluid for later section by Wolbach to determine nature of repair.

#### SUMMARY OF THE ABOVE THIRTY CASES.

- |           |   |
|-----------|---|
| CASE I.   | Pleurotomy. Death, 4th day.                               |
| CASE II.  | Application of positive pressure. Recovery.               |
| CASE III. | Pleurotomy: one rib excised. Recovery: localized empyema. |
| CASE IV.  | Pleurotomy: one rib excised. Recovery.                    |
| CASE V.   | Excision: portion middle lobe. Death, 6th day.            |
| CASE VI.  | Pleurotomy: one rib excised. Recovery.                    |

CASE VII.	Pleurotomy: one rib excised. Recovery.
CASE VIII.	Pleurotomy: two ribs excised. Recovery: empyema.
CASE IX.	Excision: tip of middle lobe. Recovery.
CASE X.	Excision: one-third of upper lobe. Recovery.
CASE XI.	Excision: one-half upper lobe. Recovery.
CASE XII.	Excision: two-thirds middle lobe. Recovery.
CASE XIII.	Excision: three right lobes. Death, 5th day.
CASE XIV.	Pleurotomy: three-rib-flap. Death, 3rd day.
CASE XV.	Excision: three-fourths middle lobe. Recovery.
CASE XVI.	Excision: three-fourths middle lobe. Recovery.
CASE XVII.	Dorsal pleurotomy. Recovery.
CASE XVIII.	Dorsal excision left lower lobe. Death, 9th day.
CASE XIX.	Excision middle lobe. Recovery.
CASE XX.	Excision one-half upper and middle lobes. Recovery.
CASE XXI.	Excision right lower lobe. Death, 3rd day.
CASE XXII.	Excision three right lobes. Death, 5th day.
CASE XXIII.	Intercostal pleurotomy without rib excision. Recovery.
CASE XXIV.	Excision three right lobes. Death, 3rd day.
CASE XXV.	Excision right lower lobe. Death, 2nd day.
CASE XXVI.	Excision right lower lobe. Recovery.
CASE XXVII.	Clamp and release of lower lobe. Recovery.
CASE XXVIII.	Excision right lower lobe. Recovery.
CASE XXIX.	Excision portions of upper and middle lobes. Recovery.
CASE XXX.	Total excision upper and middle lobes. Recovery.
Total: 9 deaths; 21 recoveries.	

*Conclusions.*—I think I am not mistaken in stating that the foregoing shows a lower death rate in experimental operations on the lungs and pleura than has hitherto been reported.

From this practical test of the suitability of the positive pressure method of inflation for intra-thoracic surgical procedures, I am convinced that, at least for experimental laboratory work, a positive pressure apparatus such as I recommended in photograph D entirely obviates the necessity of the negative pressure cabinet. I refer not to physiological experimentation alone, but to laboratory operations on the thorax in which recovery is desired. In the above enumerated cases, I do not ascribe a single death to the use of positive inflation as such. Neither do I recognize symptoms after operation which can be justly attributed to the use of positive pressure.

It remains for me to further justify the reliability of this method by making blood pressure tracings of the pul-

monary and aortic systems to test whether, under proper control of the apparatus disturbances in these factors are any greater than those resulting from the negative pressure method. By further investigation I hope also to determine the absolute cause of pleuritic effusion and death following total one-sided pneumectomy, and to test different methods of thoracoplasty, including artificially produced mediastinal and diaphragmatic herniæ, with the object of at least partially obliterating the unoccupied cavity. I recognize that successful total pneumectomies of normal animal lungs without thoracoplasty have been claimed, but such cases are extremely rare and I question whether such procedure will ever become a reliable one.

As a matter of fact, total extirpation of a lung would rarely be occasioned in the human except in cases of new growth, wherein the chest wall would ordinarily be involved and a thoracoplasty would be the operation of choice.

It is conceivable, then, that a large majority of deaths in the above series were caused by operative procedures which are never indicated, and under such normal conditions as are never present. Should we exclude these fatalities then, granting that the apparatus was not responsible, there is reason for encouragement from these experiments that for partial lobe excision, for exploratory operations, and for removal of foreign bodies, we have a reliable method which is not attended by the inconveniences and expense of a negative pressure cabinet. Nor has it been proved, though stated, that interlobular abscesses and other localized inflammatory conditions of the pleural cavity may not be approached through regions uninvolved, brought to the wound, walled off and drained, as in intra-abdominal operations.

In closing I will call attention again to the eight objections raised by Sauerbruch in his publication of 1904, and attempt to answer them.

1. The change in method of breathing.

Sauerbruch refers here to the method of rhythmically inflating the lungs, regardless of the normal reflex mechanism



of respiration. It is evident in the use of such an apparatus as this, and that described by Brauer, that the animal continues to breathe in normal fashion, but is assisted in so doing by air compression which prevents lung collapse.

2. Interstitial emphysema of the lung as a result of artificial in-pumping of air.

It may be stated that in the above thirty cases no evidence of emphysema have been recognized macroscopically. It is probable that the microscopic sections will show localized emphysema in the region of the lung stumps. A great effort has been made to prevent distention of the lung beyond its normal limits, and when such conditions are maintained there is no apparent reason for the development of emphysema.

3. The effect on the circulation.

I have made no observations on pulmonary blood pressure during the existence of positive pressure. I believe, however, that if the resistance to the lung is not carried to excess that the normal relations between the general and pulmonary pressures will be little disturbed. I add one of a series of tracings which I have made to show the comparatively slight respiratory and circulatory disturbances which occur in the course of such operations as the above under positive pressure.

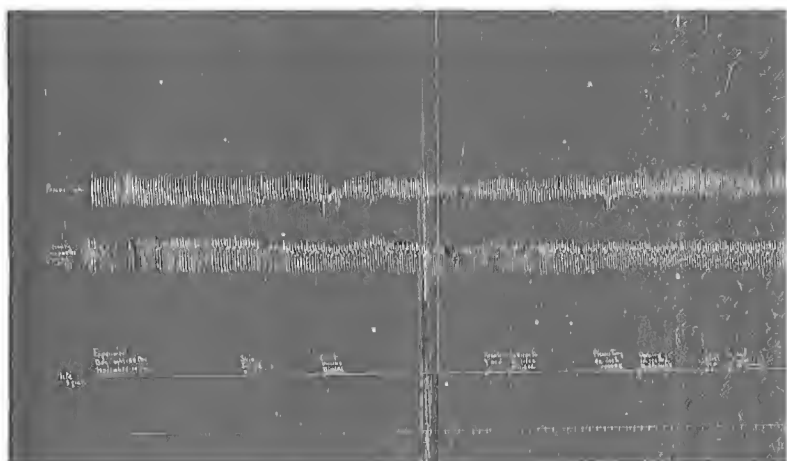
4. The persistence of pneumothorax at the abandonment of artificial inflation.

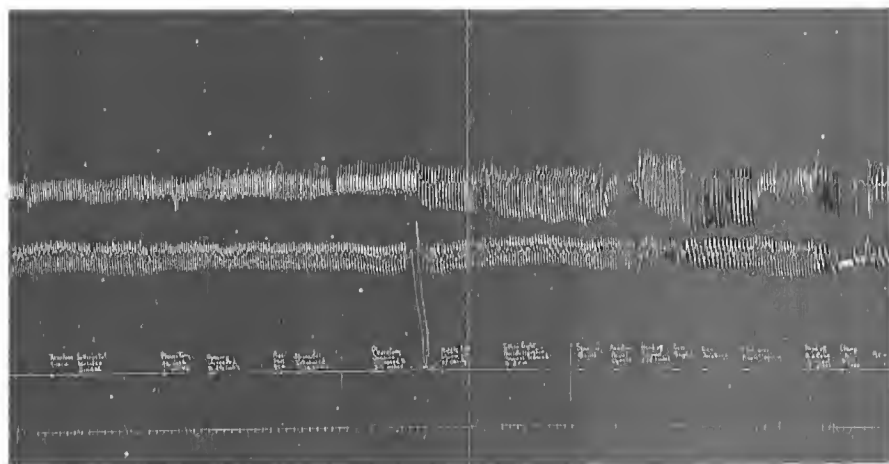
By the maintenance of the positive pressure until the thoracotomy wound is closed, exaggerated a trifle as the last pleural stitch is tied, it has, as the results indicate, been possible to avoid the persistence of a pneumothorax.

5. The great loss of heat.

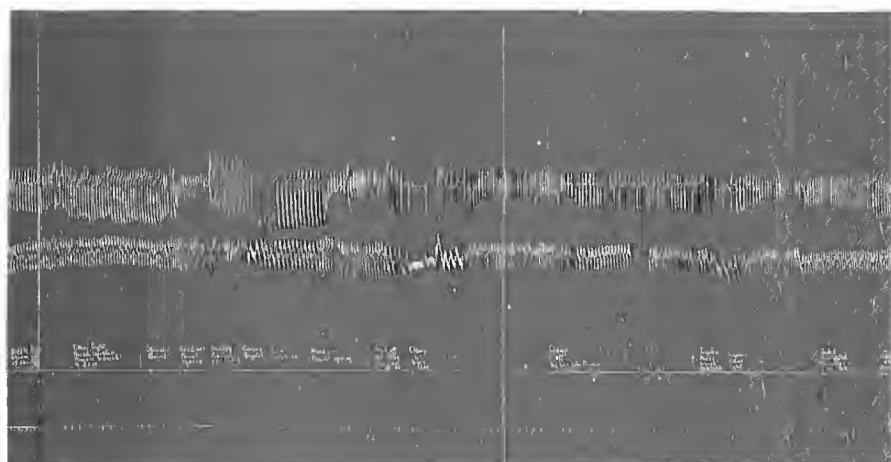
This factor must be admitted, as seen by the above records. The temperature of a cabinet is high by necessity, although that of an operating room also might be so rendered. Nor do I credit any of the above fatalities to this loss of heat.

6. The great danger of infection to the pleura as a result of the extensive air exchange in the pleural cavity.



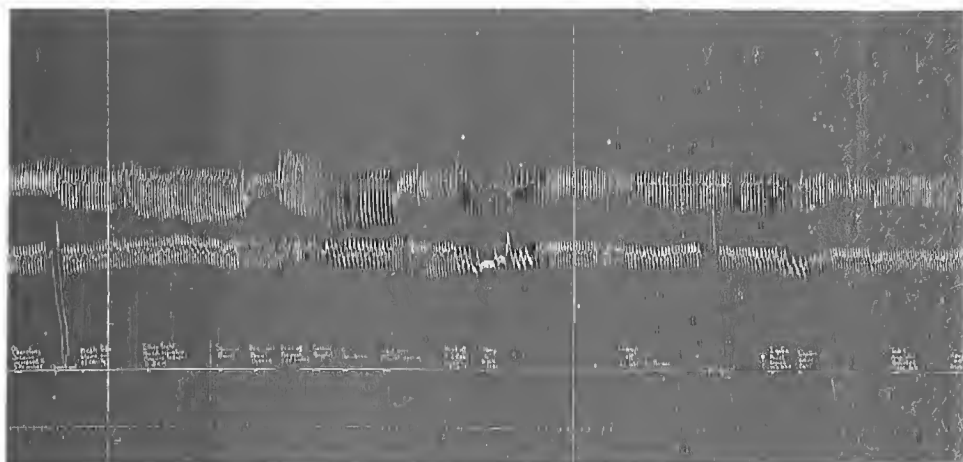


Kymograph tracing during experiment under positive pressure apparatus to show compars

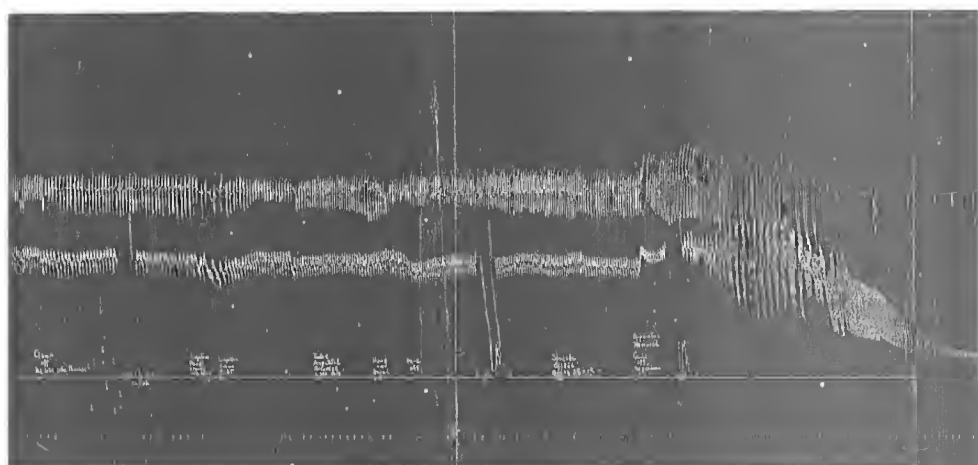


Kymograph tracing during experiment under positive pressure apparatus to show comparative slight changes in aortic blood pressure and respiratory curves, during maintenance of

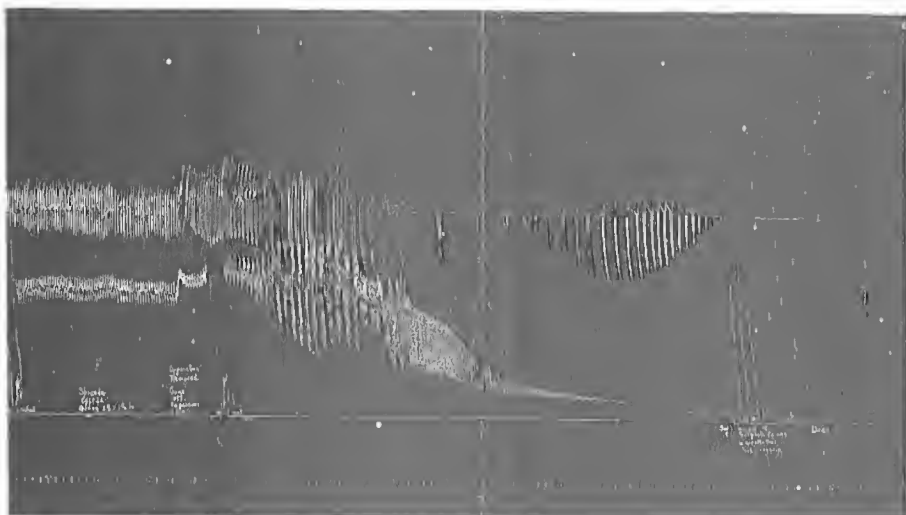




Kymograph tracing during experiment under positive pressure apparatus to show comparative slight changes in aortic blood pressure and respiratory curves, during maintenance of



changes in aortic blood pressure and respiratory curves, during maintenance of pressure.



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This danger is doubtless present. If infectious organisms are in the vicinity, however, it would seem difficult to exclude them from a pneumatic chamber.

7. The necessity of tracheotomy.

This is obviated by the use of an air tight mask, as shown in photograph. In this a great advantage can be claimed over many of the well-known respiratory devices in which tracheotomy is necessary.

8. The difficulty of narcosis.

This difficulty has not been experienced in the application of this apparatus. The animals have been evenly anesthetized, and none have been lost from over-etherization.

I gratefully acknowledge the assistance and encouragement given to me in this investigation by Prof. Walter B. Cannon of the Physiological Department. Through his courtesy and help I have become familiar with the use of physiological apparatus and technique which have enabled me to make certain observations along the lines of pathological physiology which will be reported in a second paper.

For reports and consultation in connection with the pathological aspects my thanks are due to S. B. Wolbach of the Pathological Department.

The apparatus and new instruments were executed by H. M. Webber, mechanic at the Harvard Medical School.